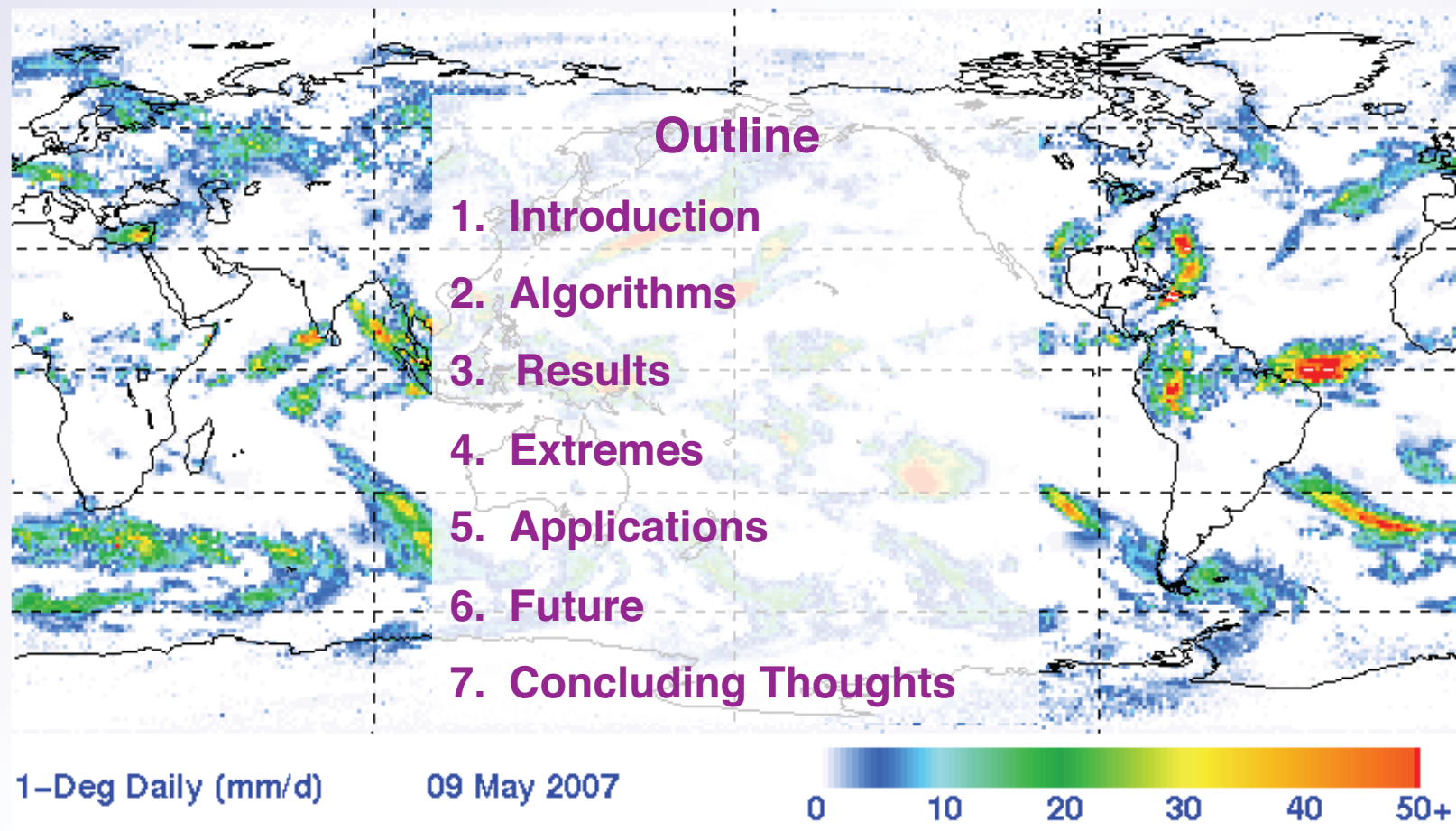


# Estimating Global Precipitation for Science and Application

George J. Huffman  
NASA Goddard Space Flight Center



# 1. INTRODUCTION – the Precip Group

Development, maintenance, user support, analysis, applications

- Bob Adler (ESSIC)
- Dave Bolvin (SSAI)
- George Huffman (NASA)
- Eric Nelkin (SSAI)

Collaborate with analysis and applications

- Guojun Gu (ESSIC)
- Dalia Kirschbaum (NASA)
- Matt Sapiano (ESSIC)
- Yudong Tian (ESSIC)
- J.J. Wang (ESSIC)

Active alumni

- Scott Curtis (East Carolina Univ.)
- Yang Hong (Univ. of Oklahoma)
- Koray Yilmaz (Middle East Tech. Univ., Turkey)

# 1. INTRODUCTION – Rain is easy to measure, hard to analyze

The physical process is hard to cope with:

- rain is generated on the microscale
- the decorrelation distance/ time is short
- point values only represent a small area & snapshots only represent a short time
- a finite number of samples causes problems



Image courtesy of the University Corporation for Atmospheric Research



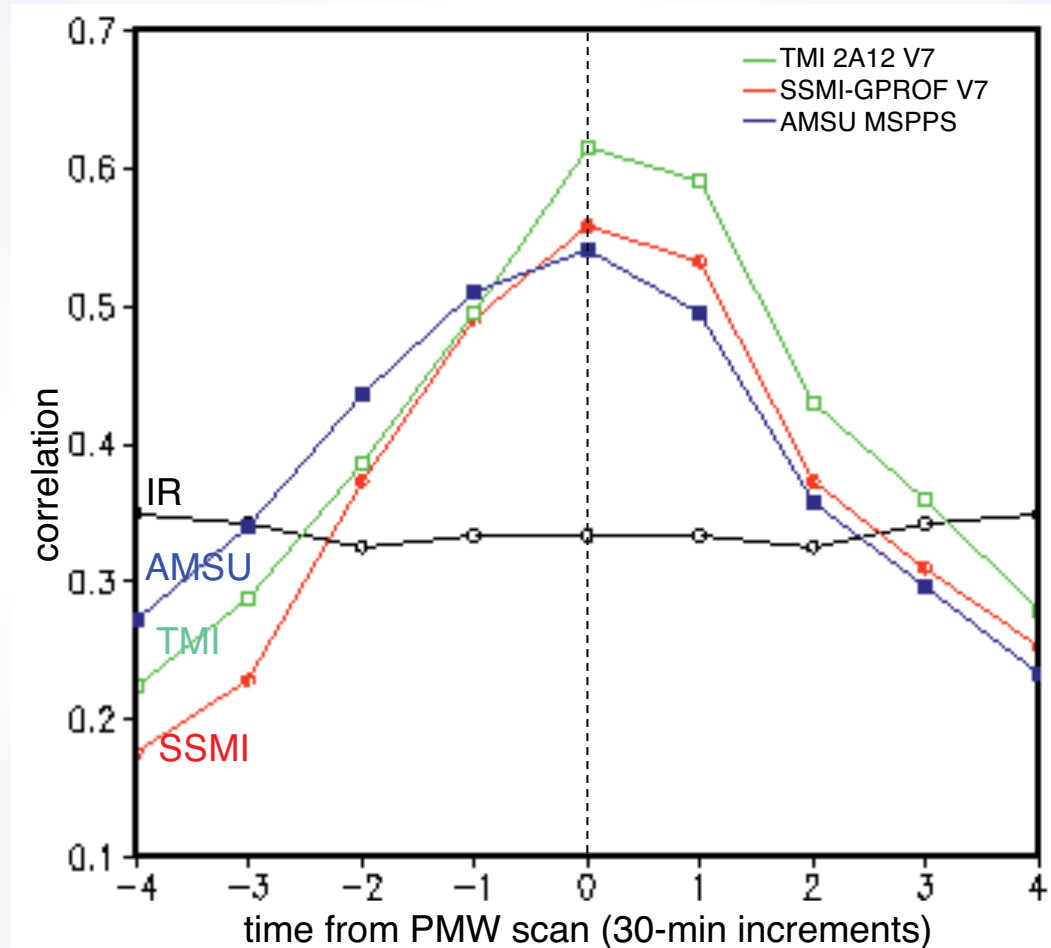
## Rainfall for DC area, July 1994

- 
- This is a detailed weather map of the Washington, D.C. metropolitan area and surrounding regions. The map displays various weather features including:
- Pressure Systems:** High-pressure areas (H) and low-pressure areas (L) are marked with their respective values (e.g., 1012, 1008, 1004, 1000, 996, 992, 988, 984, 980, 976, 972, 968, 964, 960, 956, 952, 948, 944, 940, 936, 932, 928, 924, 920, 916, 912, 908, 904, 900, 896, 892, 888, 884, 880, 876, 872, 868, 864, 860, 856, 852, 848, 844, 840, 836, 832, 828, 824, 820, 816, 812, 808, 804, 800, 796, 792, 788, 784, 780, 776, 772, 768, 764, 760, 756, 752, 748, 744, 740, 736, 732, 728, 724, 720, 716, 712, 708, 704, 700, 696, 692, 688, 684, 680, 676, 672, 668, 664, 660, 656, 652, 648, 644, 640, 636, 632, 628, 624, 620, 616, 612, 608, 604, 600, 596, 592, 588, 584, 580, 576, 572, 568, 564, 560, 556, 552, 548, 544, 540, 536, 532, 528, 524, 520, 516, 512, 508, 504, 500, 496, 492, 488, 484, 480, 476, 472, 468, 464, 460, 456, 452, 448, 444, 440, 436, 432, 428, 424, 420, 416, 412, 408, 404, 400, 396, 392, 388, 384, 380, 376, 372, 368, 364, 360, 356, 352, 348, 344, 340, 336, 332, 328, 324, 320, 316, 312, 308, 304, 300, 296, 292, 288, 284, 280, 276, 272, 268, 264, 260, 256, 252, 248, 244, 240, 236, 232, 228, 224, 220, 216, 212, 208, 204, 200, 196, 192, 188, 184, 180, 176, 172, 168, 164, 160, 156, 152, 148, 144, 140, 136, 132, 128, 124, 120, 116, 112, 108, 104, 100, 996, 992, 988, 984, 980, 976, 972, 968, 964, 960, 956, 952, 948, 944, 940, 936, 932, 928, 924, 920, 916, 912, 908, 904, 900, 896, 892, 888, 884, 880, 876, 872, 868, 864, 860, 856, 852, 848, 844, 840, 836, 832, 828, 824, 820, 816, 812, 808, 804, 800, 796, 792, 788, 784, 780, 776, 772, 768, 764, 760, 756, 752, 748, 744, 740, 736, 732, 728, 724, 720, 716, 712, 708, 704, 700, 696, 692, 688, 684, 680, 676, 672, 668, 664, 660, 656, 652, 648, 644, 640, 636, 632, 628, 624, 620, 616, 612, 608, 604, 600, 596, 592, 588, 584, 580, 576, 572, 568, 564, 560, 556, 552, 548, 544, 540, 536, 532, 528, 524, 520, 516, 512, 508, 504, 500, 496, 492, 488, 484, 480, 476, 472, 468, 464, 460, 456, 452, 448, 444, 440, 436, 432, 428, 424, 420, 416, 412, 408, 404, 400, 396, 392, 388, 384, 380, 376, 372, 368, 364, 360, 356, 352, 348, 344, 340, 336, 332, 328, 324, 320, 316, 312, 308, 304, 300, 296, 292, 288, 284, 280, 276, 272, 268, 264, 260, 256, 252, 248, 244, 240, 236, 232, 228, 224, 220, 216, 212, 208, 204, 200, 196, 192, 188, 184, 180, 176, 172, 168, 164, 160, 156, 152, 148, 144, 140, 136, 132, 128, 124, 120, 116, 112, 108, 104, 100, 996, 992, 988, 984, 980, 976, 972, 968, 964, 960, 956, 952, 948, 944, 940, 936, 932, 928, 924, 920, 916, 912, 908, 904, 900, 896, 892, 888, 884, 880, 876, 872, 868, 864, 860, 856, 852, 848, 844, 840, 836, 832, 828, 824, 820, 816, 812, 808, 804, 800, 796, 792, 788, 784, 780, 776, 772, 768, 764, 760, 756, 752, 748, 744, 740, 736, 732, 728, 724, 720, 716, 712, 708, 704, 700, 696, 692, 688, 684, 680, 676, 672, 668, 664, 660, 656, 652, 648, 644, 640, 636, 632, 628, 624, 620, 616, 612, 608, 604, 600, 596, 592, 588, 584, 580, 576, 572, 568, 564, 560, 556, 552, 548, 544, 540, 536, 532, 528, 524, 520, 516, 512, 508, 504, 500, 496, 492, 488, 484, 480, 476, 472, 468, 464, 460, 456, 452, 448, 444, 440, 436, 432, 428, 424, 420, 416, 412, 408, 404, 400, 396, 392, 388, 384, 380, 376, 372, 368, 364, 360, 356, 352, 348, 344, 340, 336, 332, 328, 324, 320, 316, 312, 308, 304, 300, 296, 292, 288, 284, 280, 276, 272, 268, 264, 260, 256, 252, 248, 244, 240, 236, 232, 228, 224, 220, 216, 212, 208, 204, 200, 196, 192, 188, 184, 180, 176, 172, 168, 164, 160, 156, 152, 148, 144, 140, 136, 132, 128, 124, 120, 116, 112, 108, 104, 100, 996, 992, 988, 984, 980, 976, 972, 968, 964, 960, 956, 952, 948, 944, 940, 936, 932, 928, 924, 920, 916, 912, 908, 904, 900, 896, 892, 888, 884, 880, 876, 872, 868, 864, 860, 856, 852, 848, 844, 840, 836, 832, 828, 824, 820, 816, 812, 808, 804, 800, 796, 792, 788, 784, 780, 776, 772, 768, 764, 760, 756, 752, 748, 744, 740, 736, 732, 728, 724, 720, 716, 712, 708, 704, 700, 696, 692, 688, 684, 680, 676, 672, 668, 664, 660, 656, 652, 648, 644, 640, 636, 632, 628, 624, 620, 616, 612, 608, 604, 600, 596, 592, 588, 584, 580, 576, 572, 568, 564, 560, 55

# 1. INTRODUCTION – Lagrangian decorrelation time

Coincident 0.25°-gridbox PMW and Stage II radar estimates for JJAS 2007

- 3 microwave, 1 IR estimate compared to Stage II radar (over CONUS)
- same grid box for coincidence
- correlate time-lagged, advected microwave with radar
- compare to concurrent IR-radar correlation
- by  $\pm 90$  min the “good”, off-time microwave estimates are no better than the “poor” current IR



graphic courtesy of R. Joyce

# 1. INTRODUCTION – Instrumental errors

Instruments have characteristic errors:

- raingauge
  - wind losses
  - splashing
  - evaporation
  - side-wetting
  - interpolation
- radar
  - raindrop population changes
  - anomalous propagation
  - beam blockage by surface features
  - sidelobes
- satellite
  - physical retrieval errors
  - beam-filling errors
  - time-sampling
- numerical prediction models
  - computational approximations
  - initialization errors
  - errors in other parts of the computation



## 1. INTRODUCTION – But ...

Knowledge of precipitation is key to a wide range of users

Data sources do have recognized strengths:

- microwave imagers      good instantaneous results
- geo-IR                      good sampling
- satellite soundings      some info. in cold-surface conditions
- precipitation gauge      near-zero bias
- model                        complete coverage and "physics"

Different data sources are best in different regions

All have bigger errors in

- mountains
- snowy/icy regions

## 2. ALGORITHMS

A diverse, changing, uncoordinated set of input precip estimates, with various

- periods of record
- regions of coverage
- sensor-specific strengths and limitations

Seek the longest, most detailed record of “global” precip

### Requirements

- “Long-term” “global” precip estimates
- Minimal random error
- Minimal bias

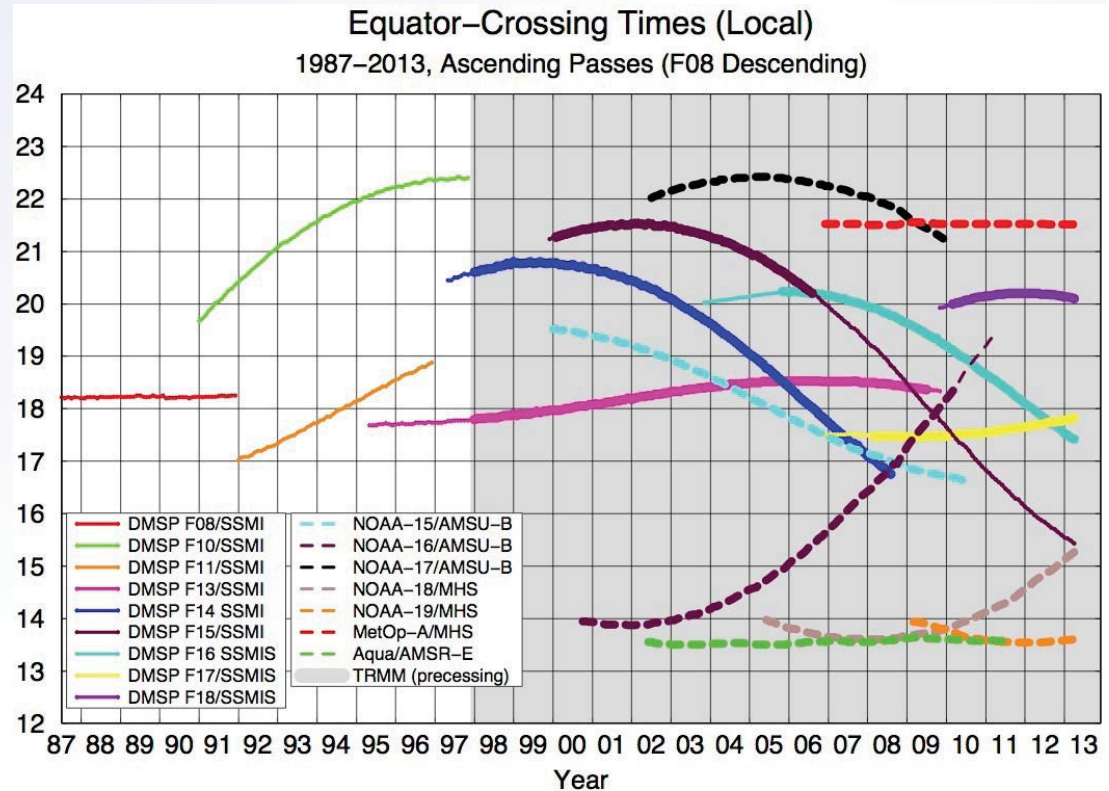


Image by Eric Nelkin (SSAI), 19 April 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

The part that (eventually)  
averages out

The part that doesn't  
average out



## 2. ALGORITHMS – Goals

We seek the longest-possible relatively homogeneous record of “global” precipitation

- Global Precipitation Climatology Project (GPCP)
  - Climate Data Record (CDR) standards
  - emphasize homogeneity over short-term answer
- TRMM Multi-satellite Precipitation Analysis (TMPA)
  - High-Resolution Precipitation Product (HRPP) approach
  - emphasize short-term answer over homogeneity
- Less-emphasized goal in each is also important, of course

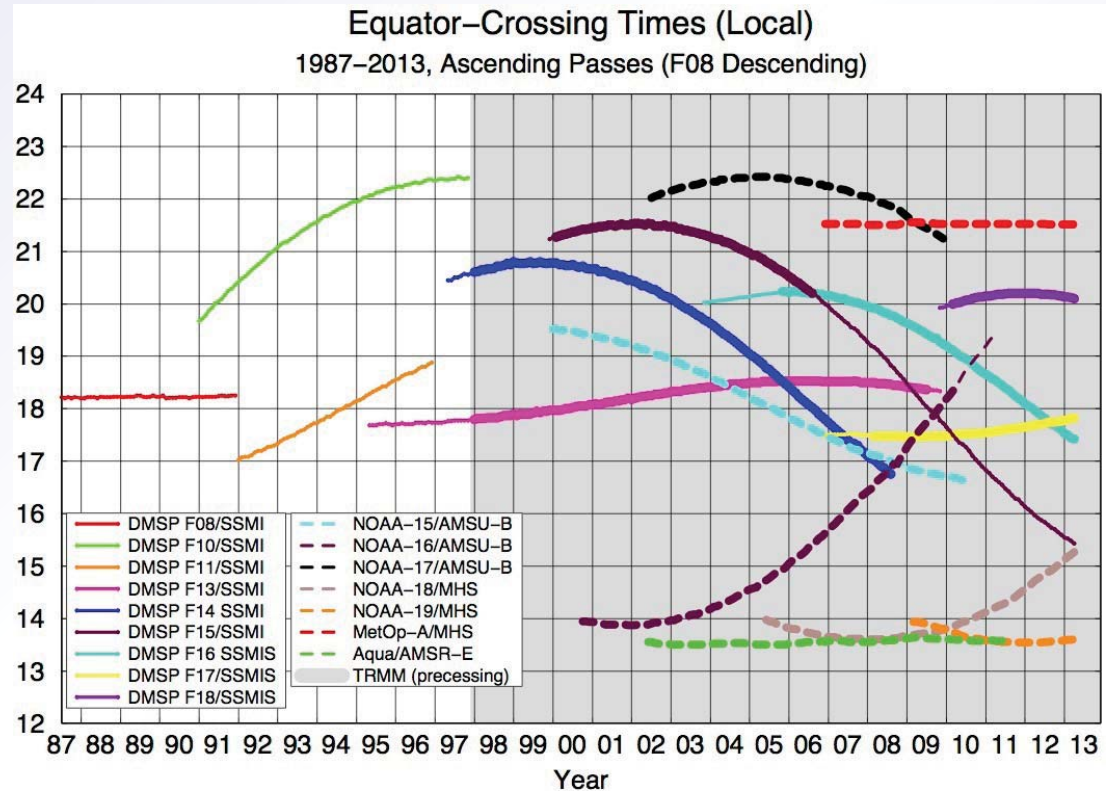


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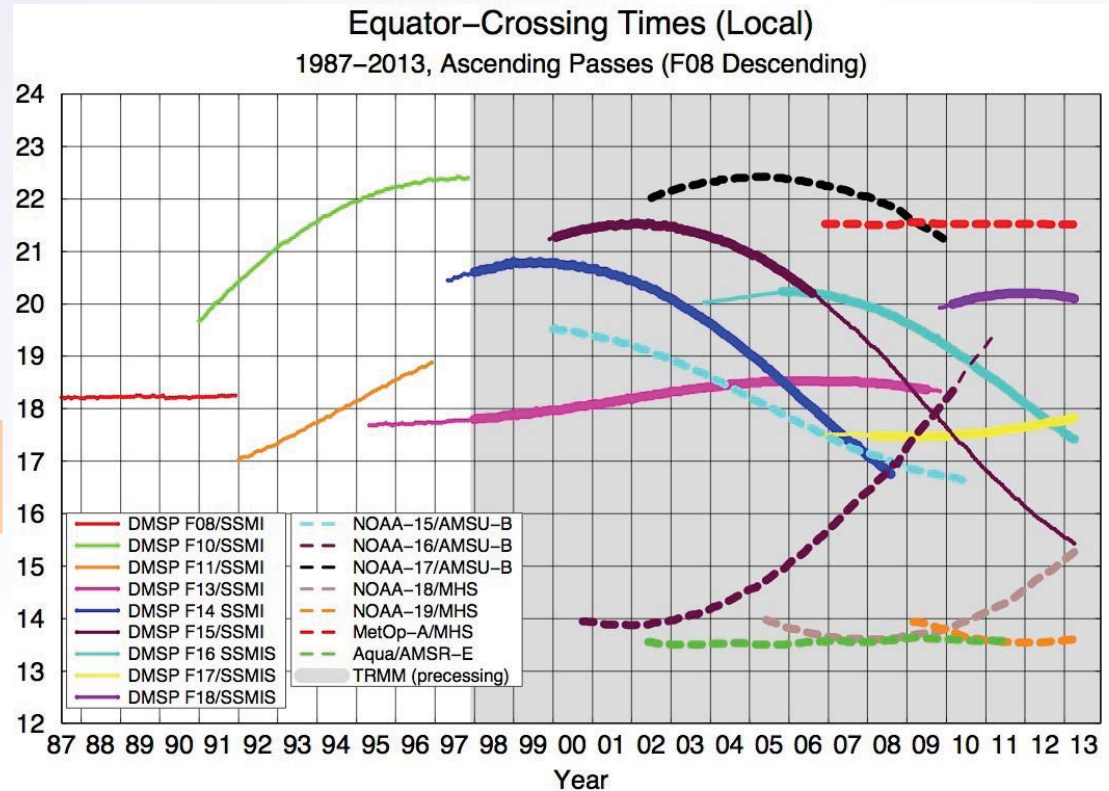


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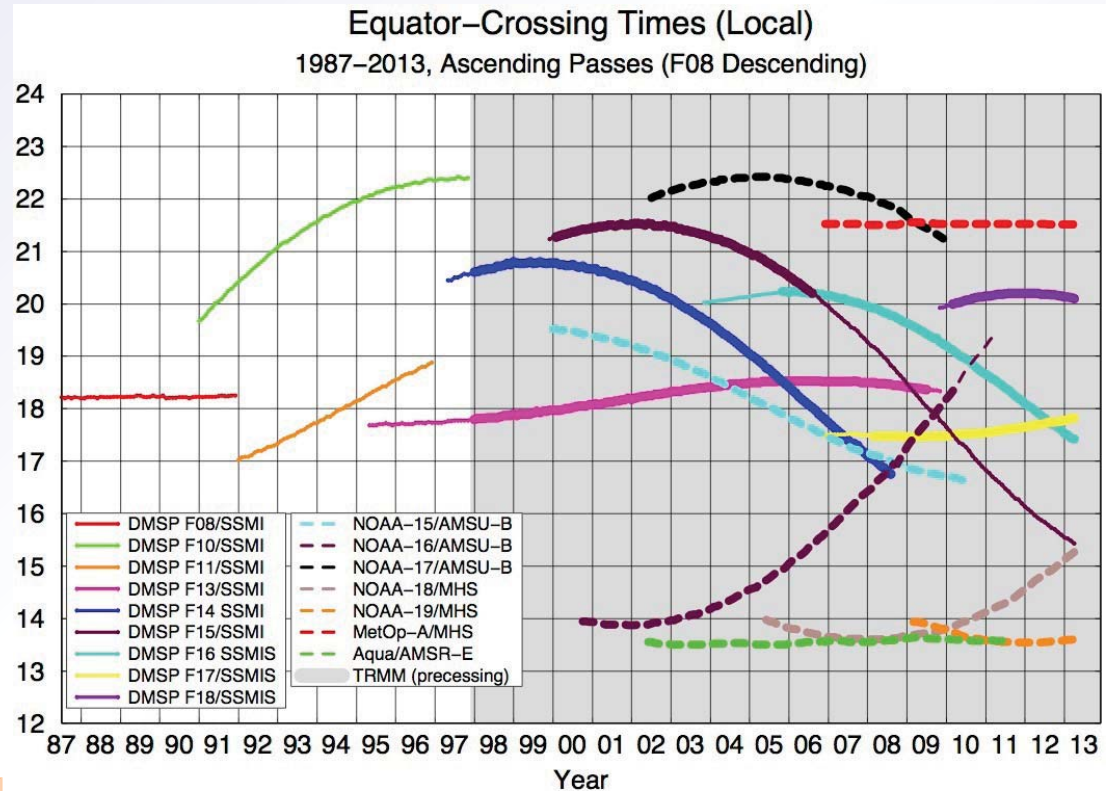


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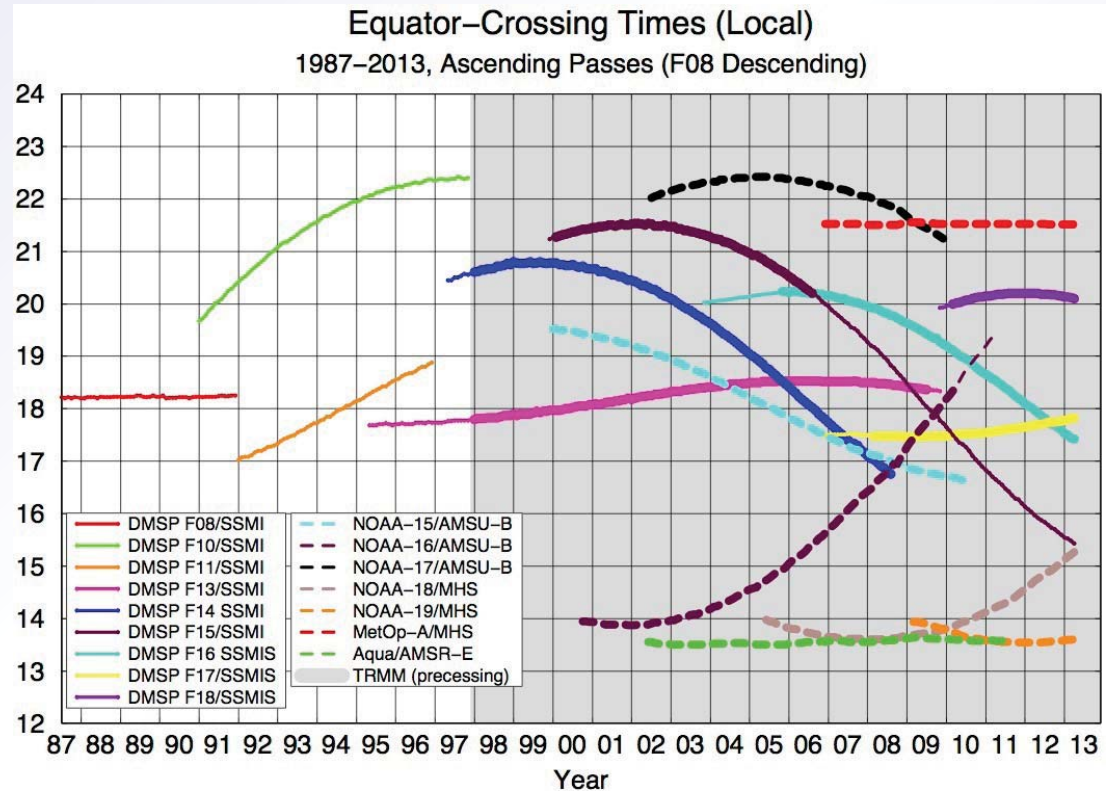


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## 2. ALGORITHMS – GPCP

International community-based project founded around 1990

- currently Adler is head of GPCP
- data from international geo-satellites (merged at NOAA)
- data from DoD, NASA, NOAA leo-satellites
- precip from groups at George Mason Univ., Deutscher Wetterdienst, NASA, NOAA

Three standard products

- final monthly satellite-gauge combination developed, computed at GSFC
- pentad (5-day) dataset developed, computed at NOAA Climate Prediction Center
- daily dataset developed, computed at GSFC
- daily and pentad adjusted to match the monthly

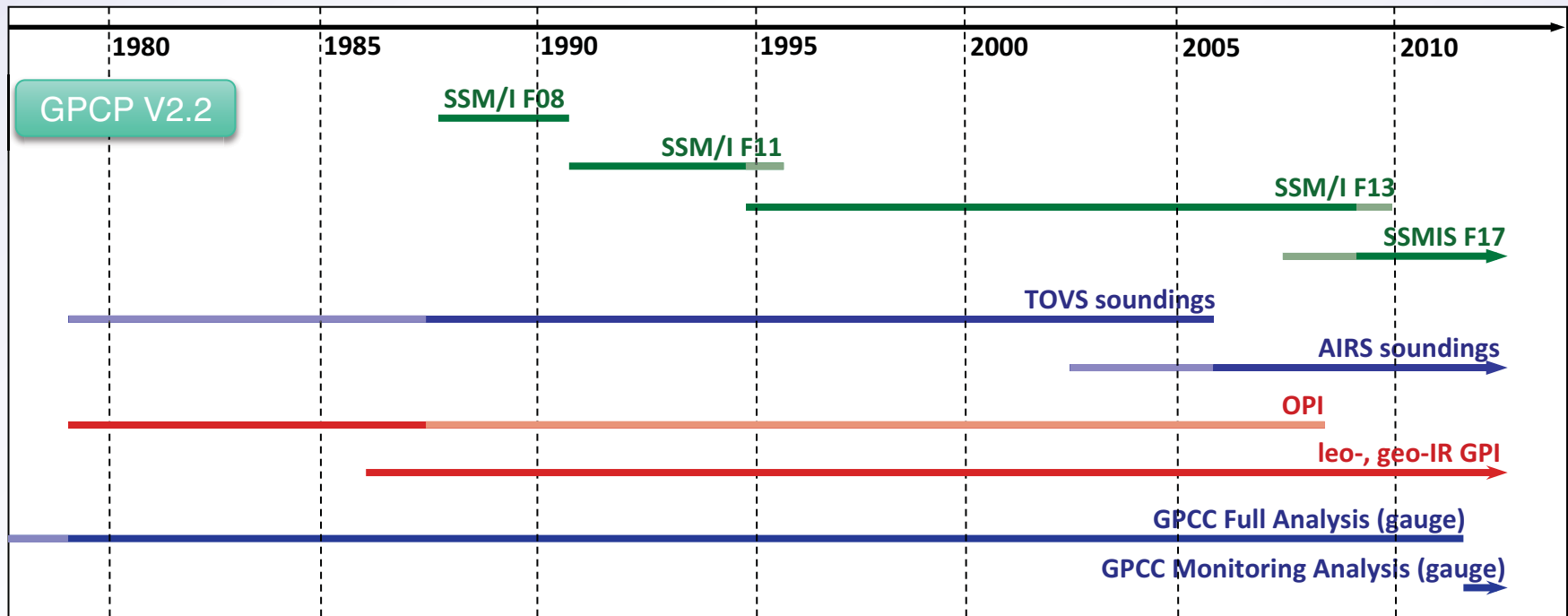
Products are an international standard

- 1500++ citations
- monthly covers 30+ years (1979 – present)

## 2. ALGORITHMS – GPCP approach

### GPCP monthly Multi-Satellite (MS)

- 1979 – July 1987
  - OLR Precipitation Index (OPI) calibrated from overlap with GPCP in the later period
- August 1987 – present
  - lower latitude: IR calibrated by single 6 a.m./p.m. sensor
    - ocean: Microwave Emission Brightness Temperature Histogram (METH) log-normal fitted-histogram microwave product
    - land: NESDIS scattering algorithm
  - higher latitude: GPCP-adjusted Susskind cloud volume proxy



## 2. ALGORITHMS – TRMM

Successful GPCP approach adapted for TRMM

- Adler, now Huffman the multi-satellite PI
- IR data from international geo-satellites (merged at NOAA)
- data from “all” DoD, EUMETSAT, NASA, NOAA passive microwave leo-satellites
- precip inputs from groups at DWD, NASA, NOAA
- key concept is inter-calibration of precip inputs to a TRMM standard product
- key result is importance of calibration by gauges to control bias

Two standard products computed after the month for the TRMM era (1998-present)

- monthly satellite-gauge combination
- 3-hourly multi-satellite dataset adjusted to sum to the monthly

Also, experimental real-time product, current version is March 2000-present

- 3-hourly multi-satellite dataset with monthly climatological adjustments

All production is done at PPS

- 0.25°x0.25° over latitudes 50°N-50°S

Standard 3-hourly is the most-requested TRMM product in the GDISC

## 2. ALGORITHMS – TMPA Approach

### “Production” TMPA monthly MS

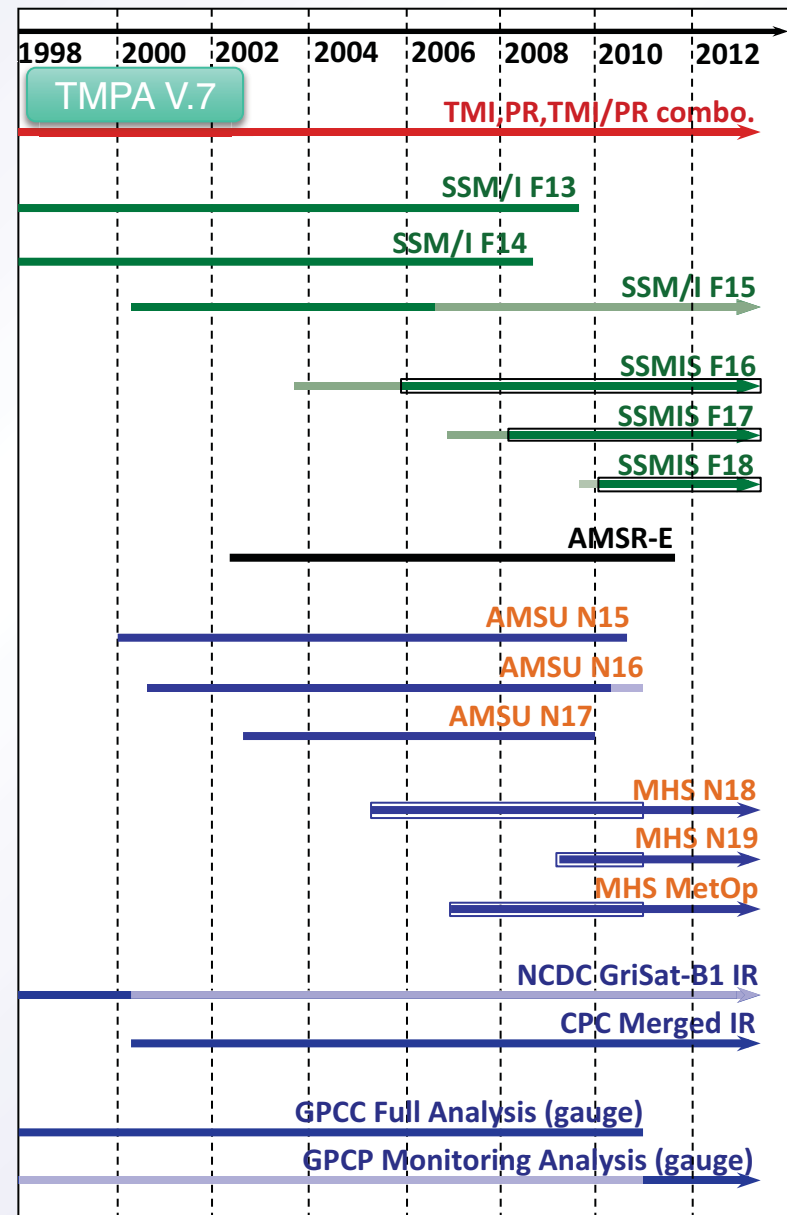
- All microwave products calibrated to TRMM Combined Instrument (TCI)
- 3-hour holes filled by microwave-calibrated IR
- 3-hour fields accumulated for monthly MS

### “Real-Time” TMPA MS

- All microwave products climatologically calibrated to TCI, 3B43
- 3-hour holes filled by microwave-calibrated IR

Periods of record not used in the datasets are shown in lighter color

Additional data records used in TMPA V.7 are boxed

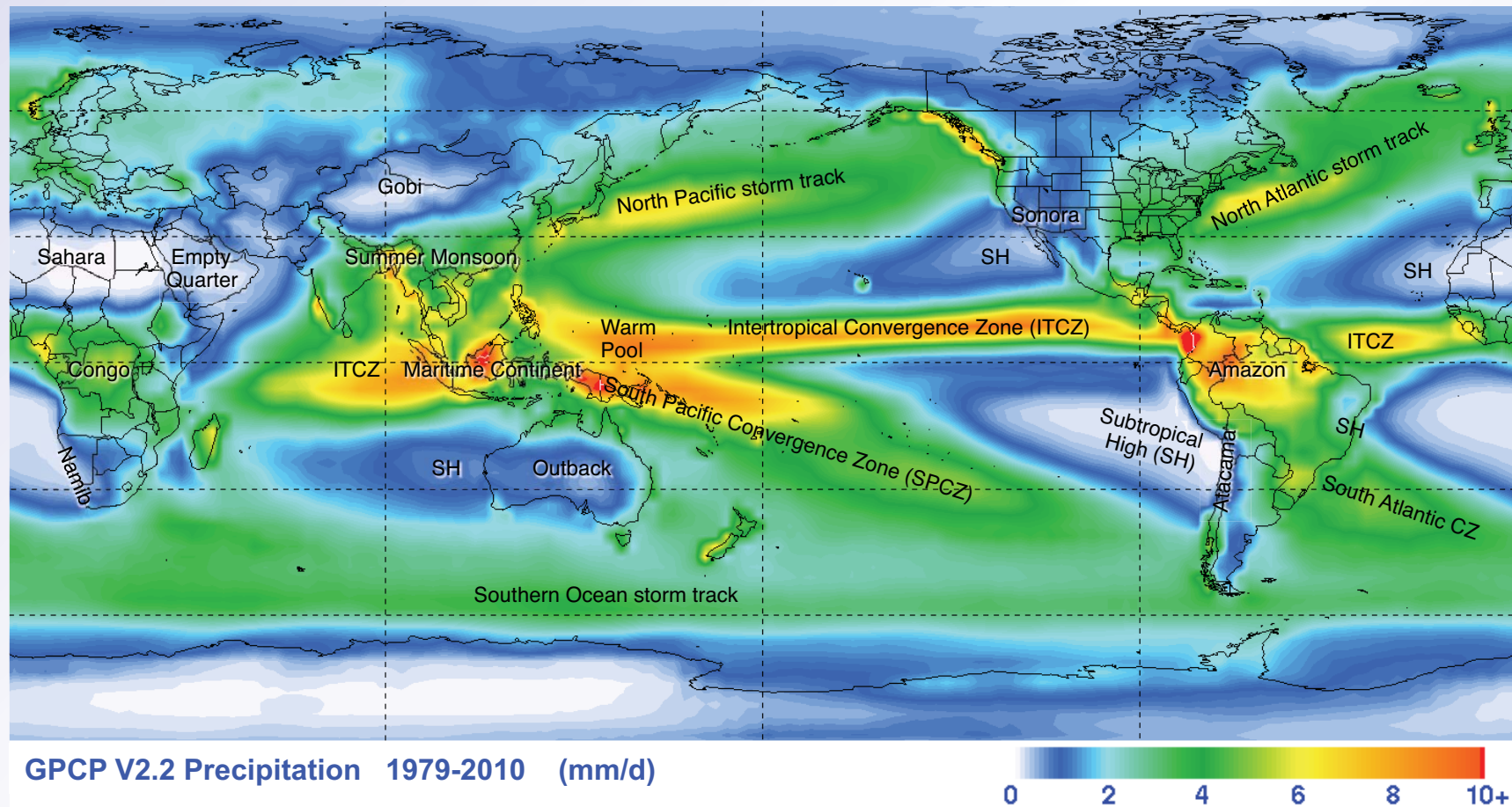




### 3. RESULTS – GPCP climatology 1979-2010

The GPCP data record is long enough that a “climatology” makes sense

Time for a crash course in naming features!



- the ITCZ – subtropical high – storm track pattern is driven by global dynamics
- asymmetries are driven by land distribution and ocean currents
- seasonal variations range from modest to extreme

### 3. RESULTS – The basic meridional circulation

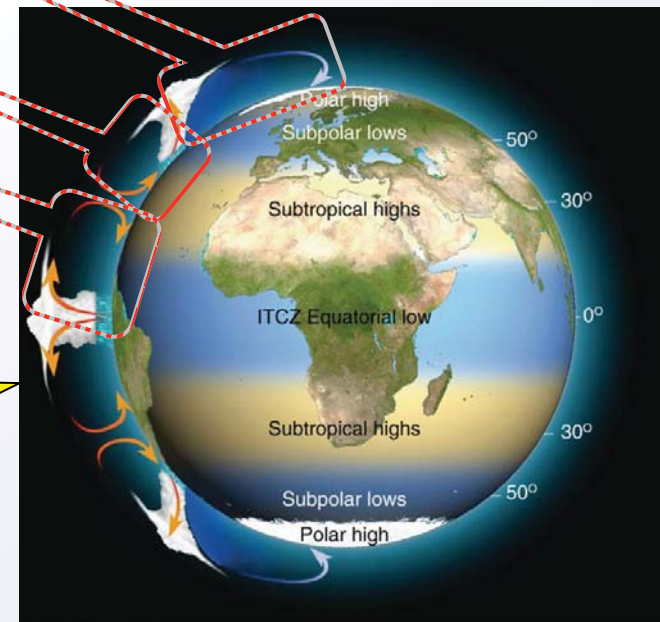
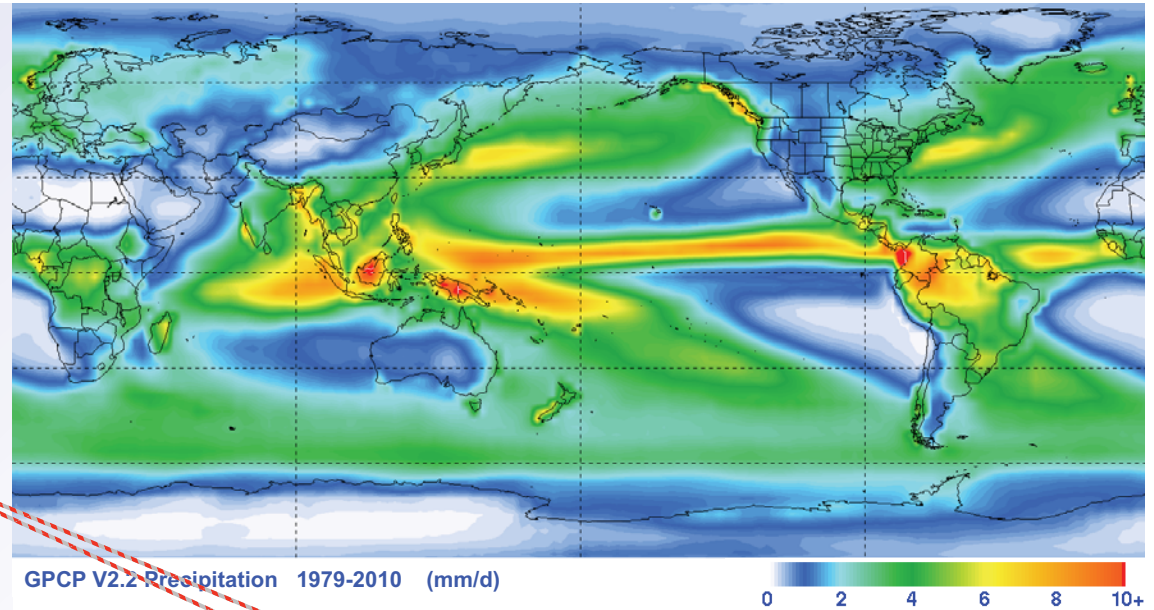
Averaging around latitude circles, there are three major “cells” of overturning air

- Polar: driven by polar cooling
- Ferrel: driven by quasi-2D baroclinic instability (low pressure systems)
- Hadley: driven by ITCZ

Precip and rising motion highly correlated in intermittent stormy regions

Dryness and sinking tend to be broad-scale

Key result:  
Precip is driven locally, but responds to large-scale dynamics



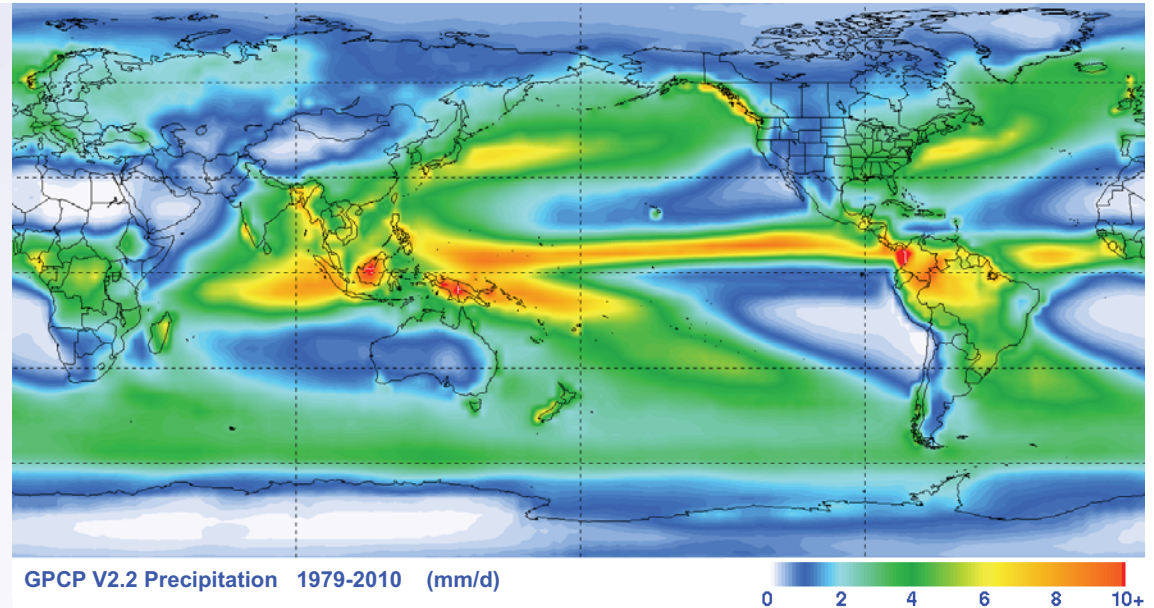
[http://apollo.lsc.vsc.edu/classes/met130/notes/chapter10/global\\_precip.html](http://apollo.lsc.vsc.edu/classes/met130/notes/chapter10/global_precip.html)



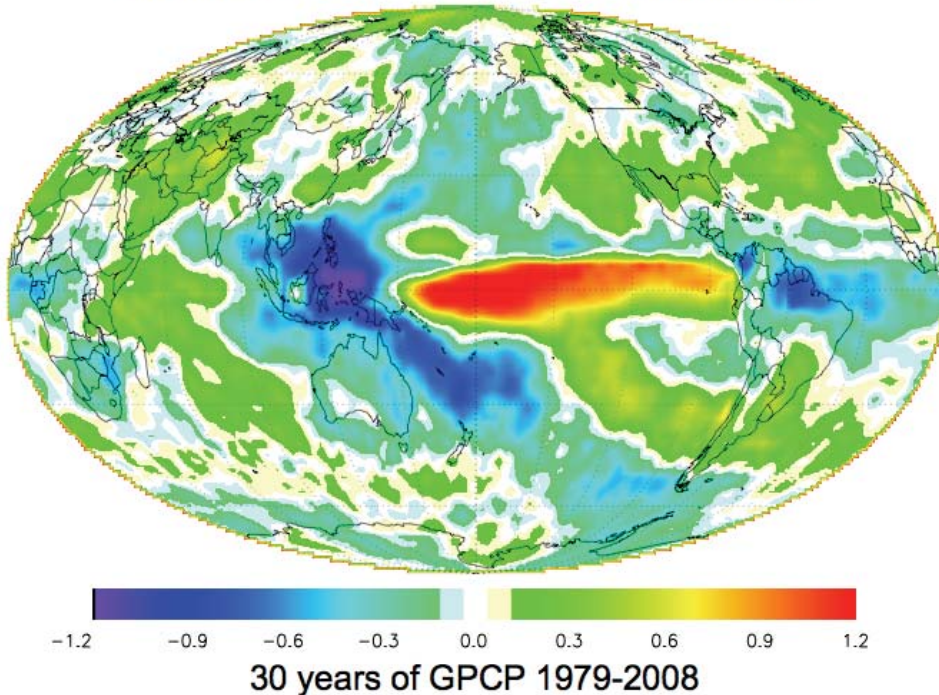
### 3. RESULTS – GPCP ENSO 1979-2008

The climatology tends to have high precip near coasts (right)

- statistics sensitive to definition of “ocean”, “land”



El Nino minus La Nina Composites  
of Global Normalized Precipitation Anomalies



The largest interannual variation is ENSO (left)

- the composite El Niño – La Niña shows the expected structure
- also, coherent bands of anomalies angle out from the tropics to mid-latitudes

### 3. RESULTS – GPCP V2.2 Time Series 1979-2012

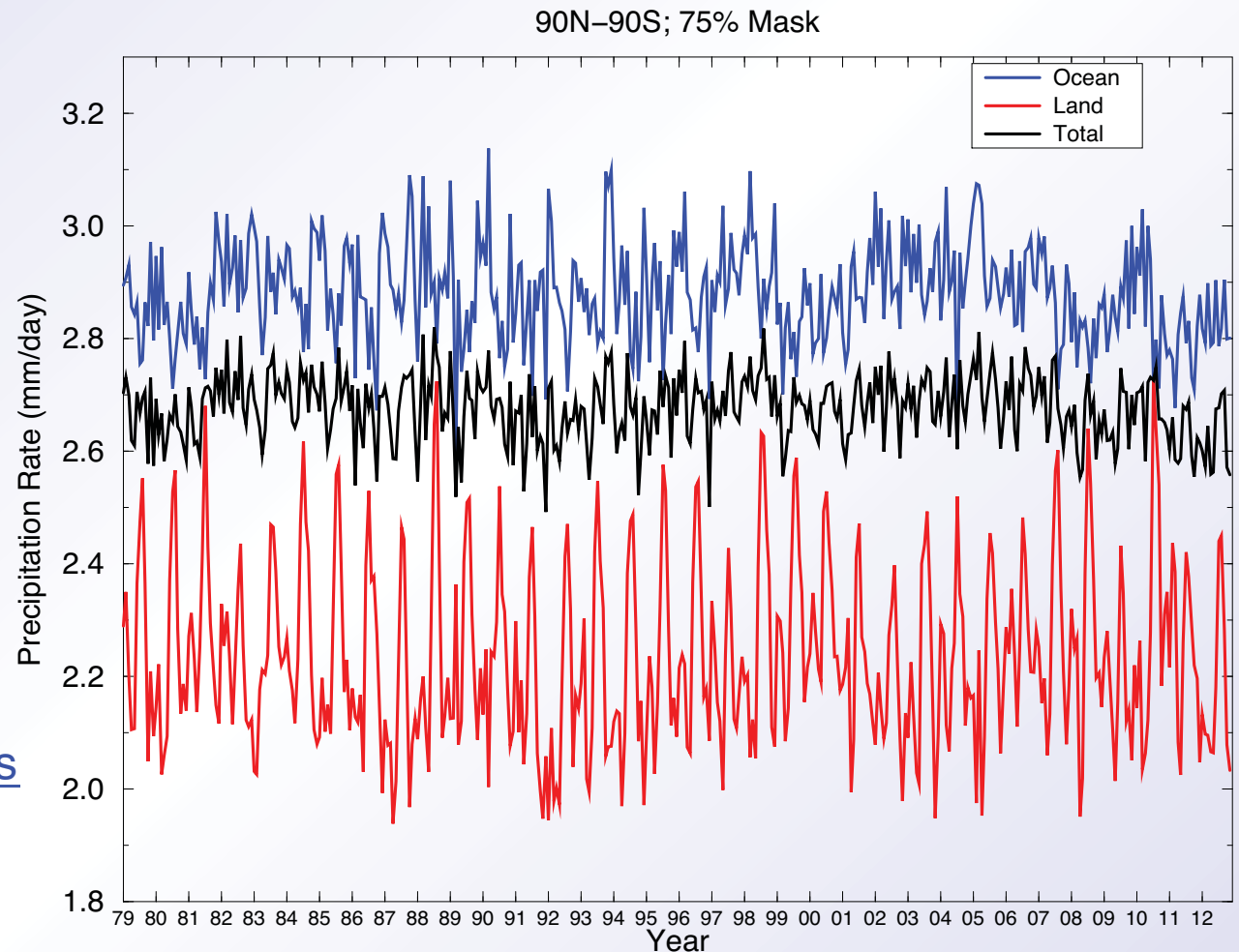
To first order, Ocean and Land are anti-correlated, creating small variations in Total

Total, Ocean have weak correlation with ENSO

Land has a strong negative leading correlation

- details sensitive to definition of “land”

Note interdecadal variations on a nearly flat trend line





### 3. RESULTS – Global change

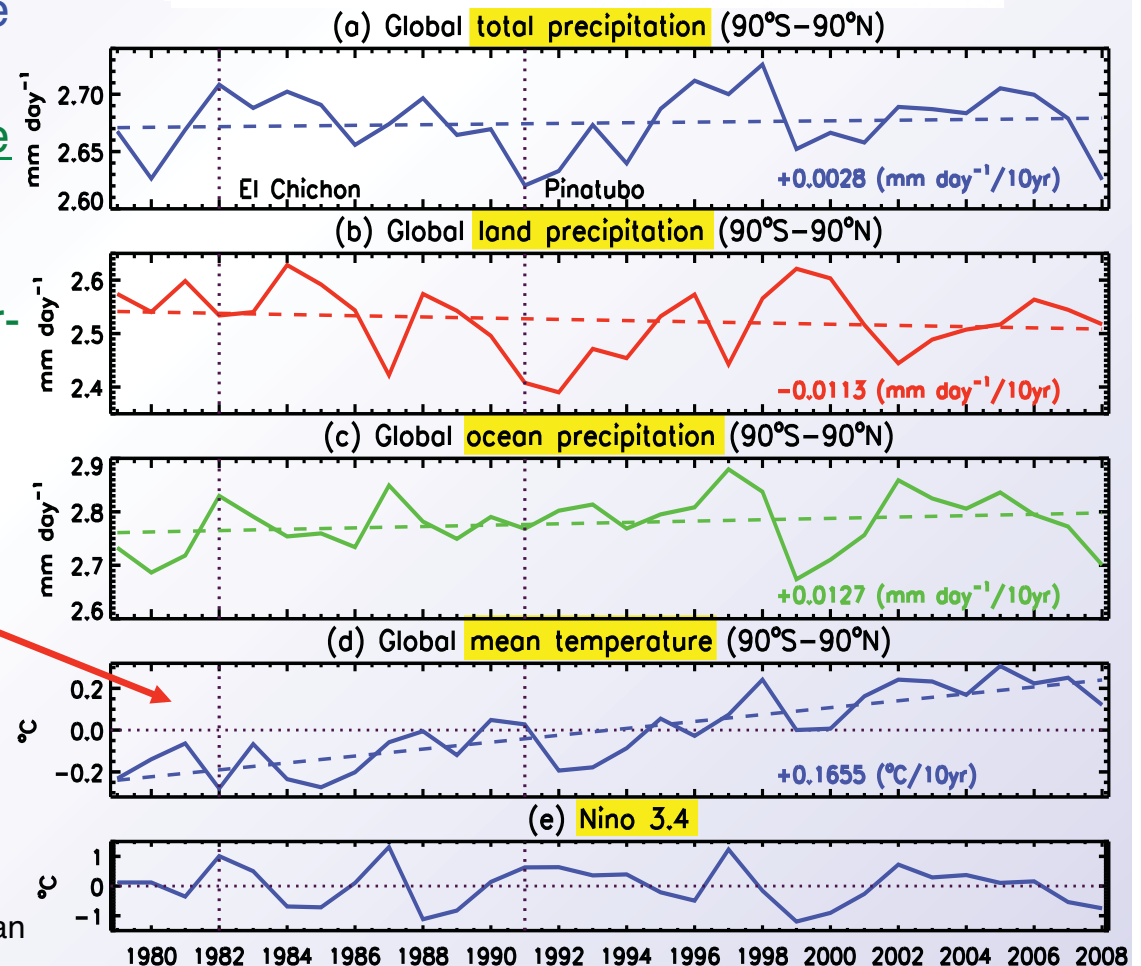
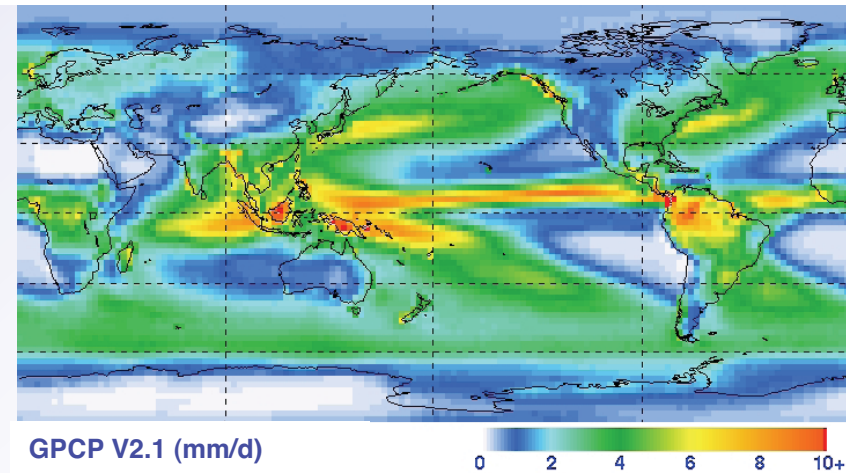
The 28-yr climatology (top) has the usual features, good continuity across coasts, reasonable high-latitude values, excellent validation

Global-average deviations from the precip climatology are modest

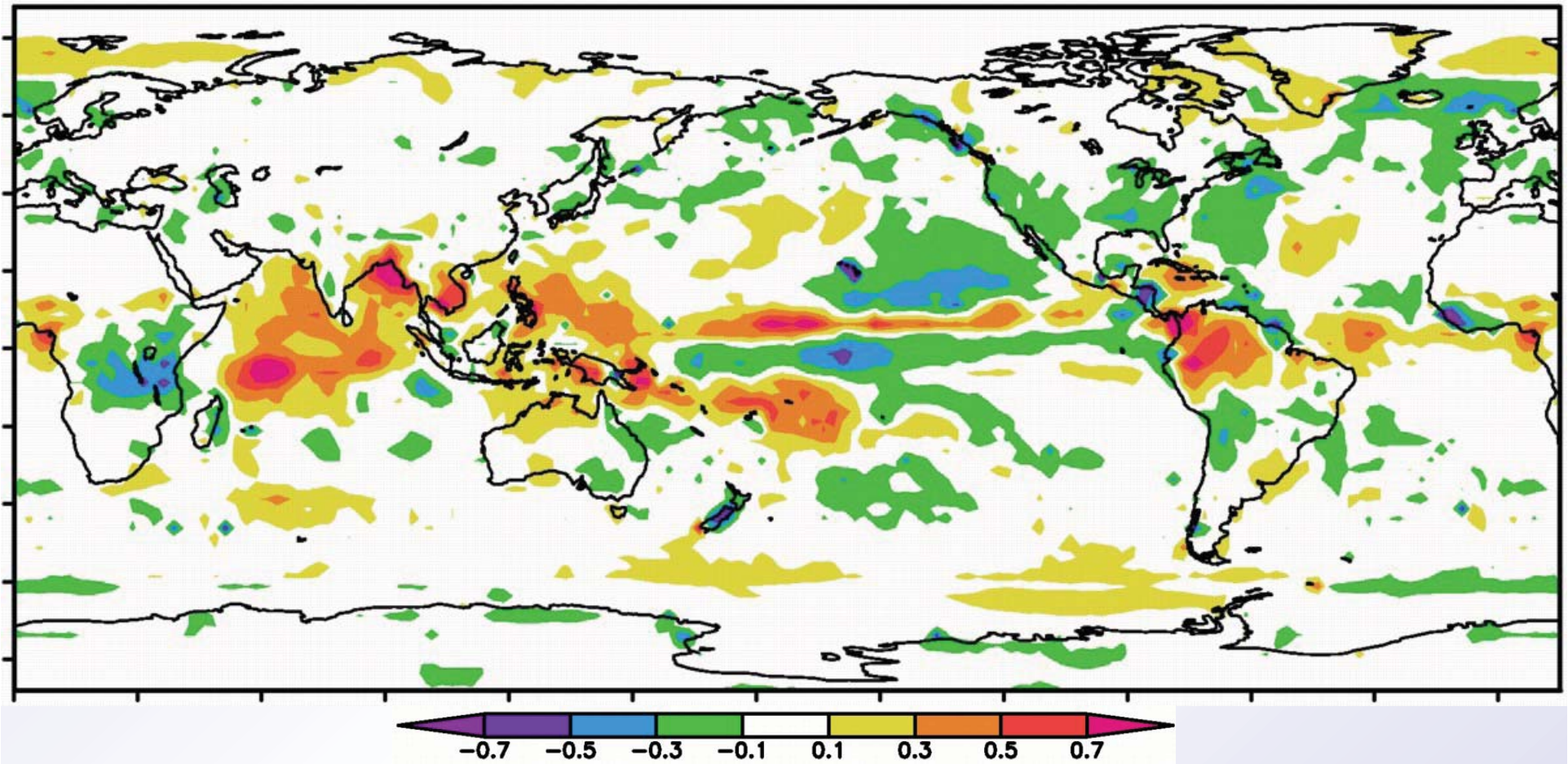
- interannual signal is the residue of opposing ENSO responses over land, ocean
- trend is small compared to inter-annual variations
- this is unlike global-mean temperature

Possible that precip extremes are changing

- requires long, homogeneous record of fine-scale precip



### 3. RESULTS – Local linear trend in GPCP V2.1 SG, 1979-2007 (29 years)



Regionally coherent trends do exist

- $>0.7$  mm/d/decade linear trend over 29 years, locally
- the pattern appears to be driven by ENSO and Pacific Decadal Oscillation
- data set inhomogeneities require careful examination

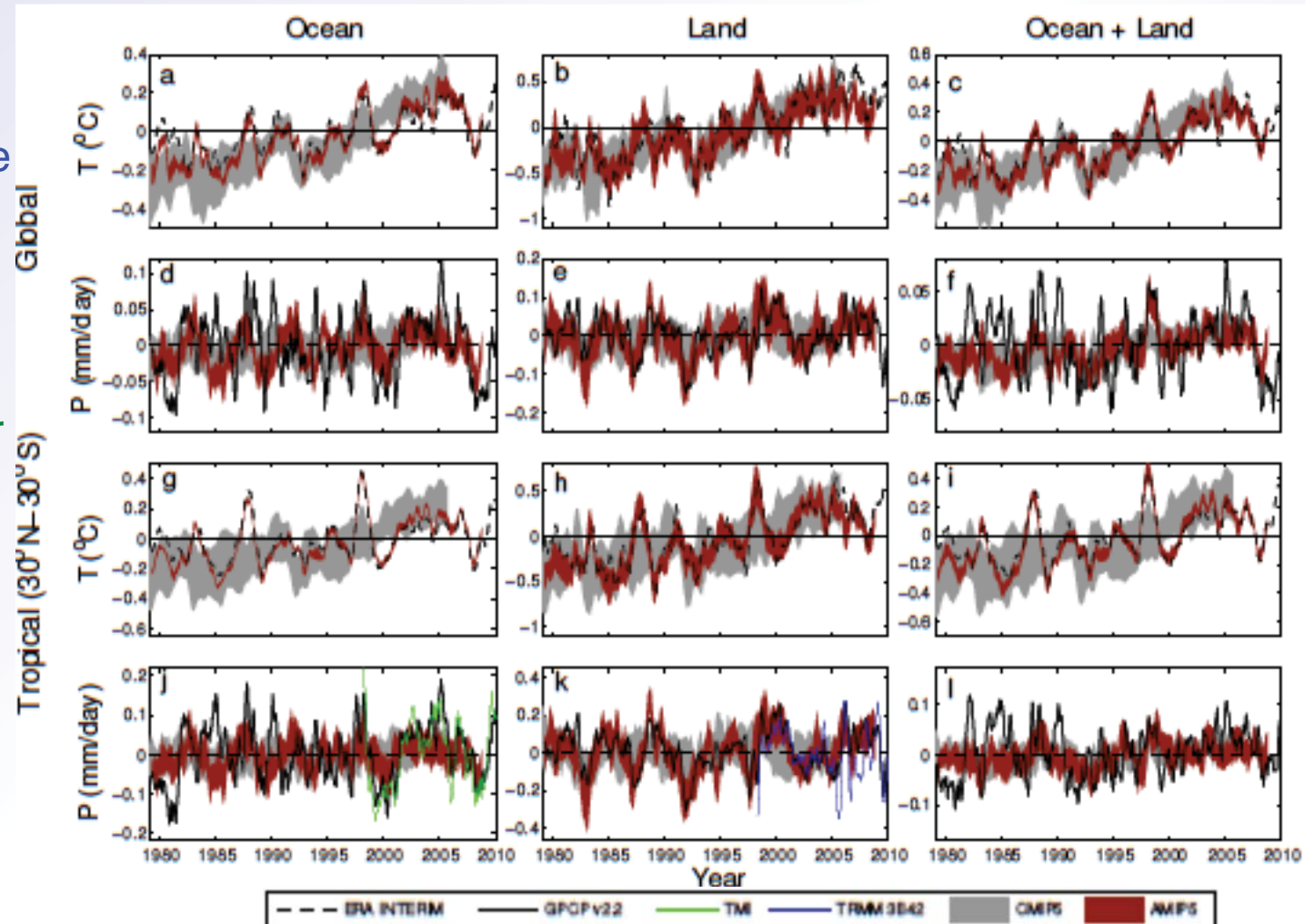


### 3. RESULTS – Comparing AMIP5, CMIP5, and observations

How well do the AMIP5 and CMIP5 models reproduce observed large-scale behavior?

Liu, Allan, Huffman, 2012, *GRL*

- CMIP5 has wider short-interval spread, but less interannual
- there is much better AMIP5-observation agreement for T than for P
- observed P variability is larger than in AMIP5
- AMIP5-observation P correlation is better over land than ocean



### 3. RESULTS – Climatologies

#### TMPA V7 (blue)

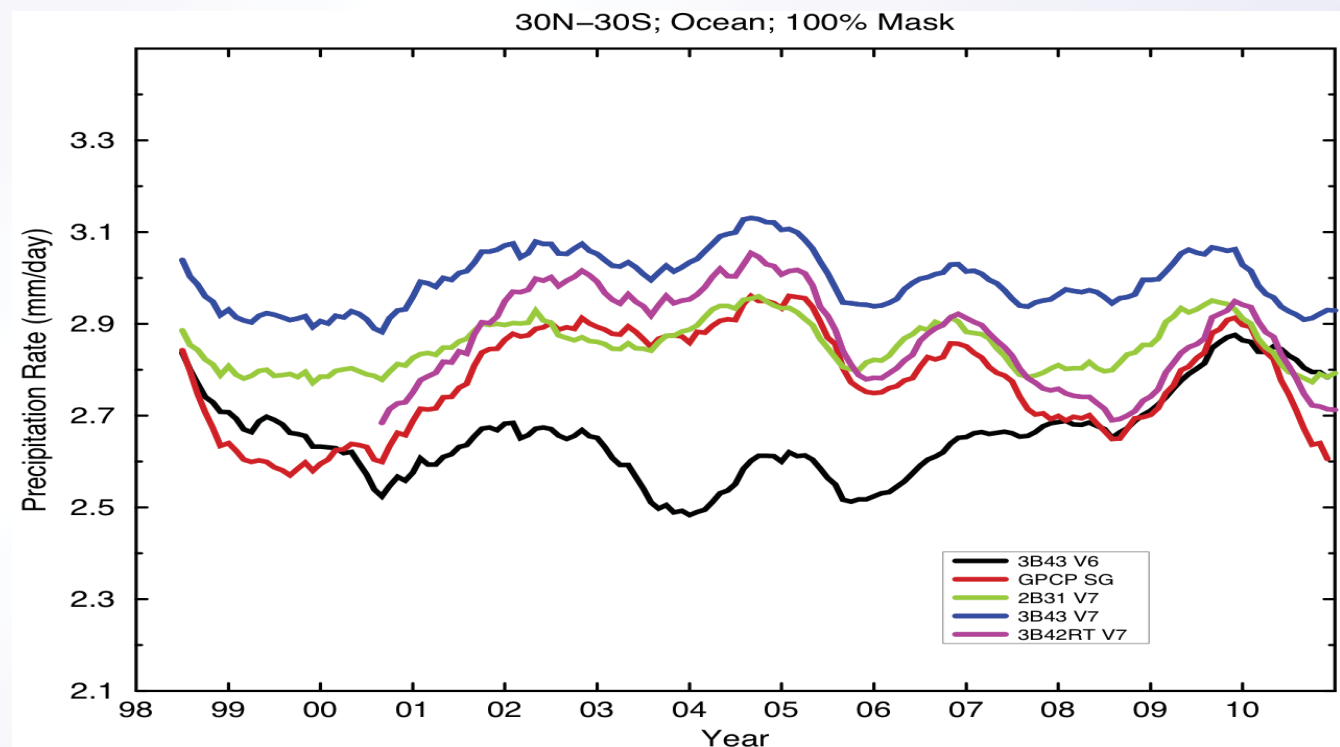
- fixes “sag” in V6 (black) with consistently processed AMSU
- follows 2B31 calibrator (green), but is 5-8% high for unknown reasons

#### GPCP (red)

- tends to have lower interannual lows than 2B31
- tends to have a 3-6 month phase lag

#### TMPA-RT V7 (magenta)

- similar to GPCP pattern
- both have microwave calibration month-to-month, vs. PR data in TCI





## 4. EXTREMES – Motivation

Precipitation has significant inter-decadal fluctuations

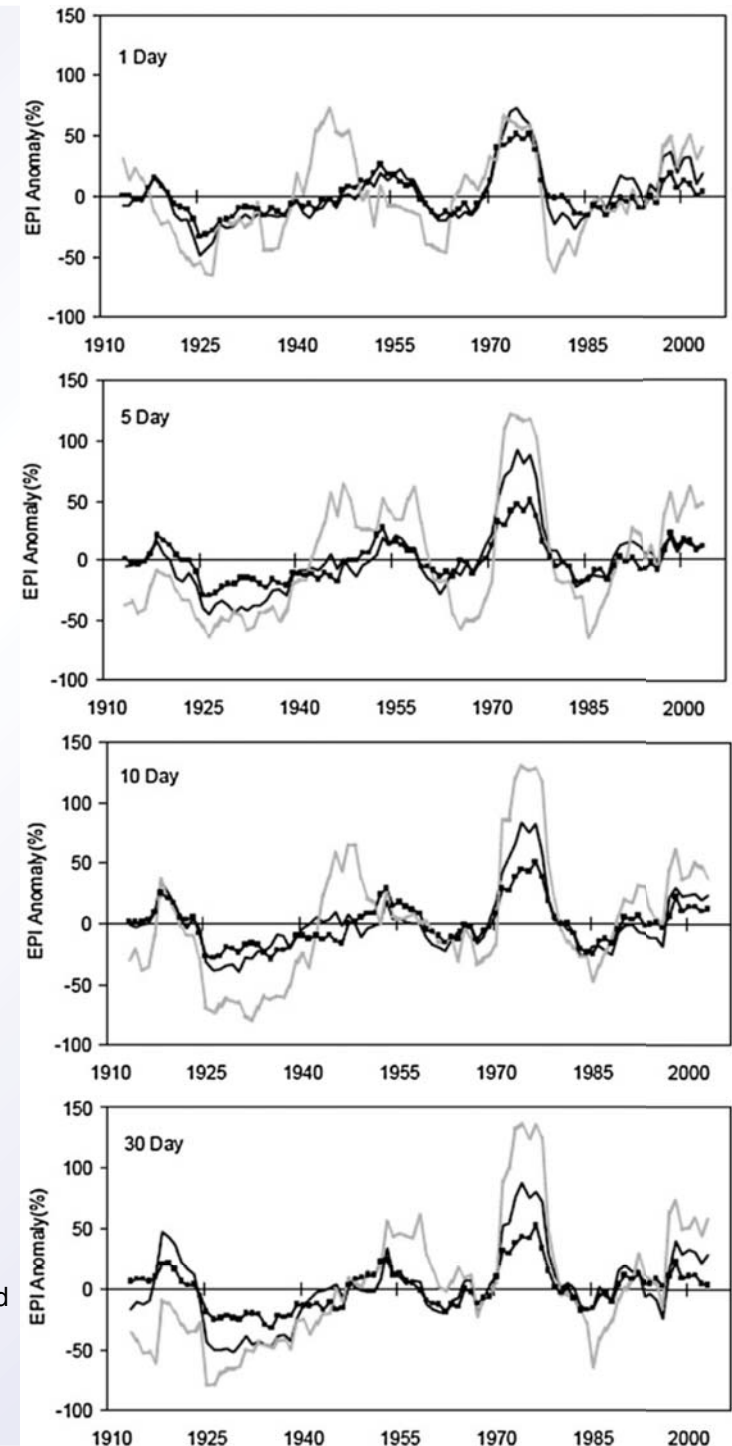
- “red”, “fat tail”
- Fu et al. (2010) show this with a century of Australian gauge data
- but, gauges are too sparse
- the longest satellite-based record is 32 years – a typical inter-decadal cycle

How do we connect the long gauge-based extremes record to the governing state variables to enable inference about the future?

How do we connect the gauge and satellite records to fill in extremes estimates where historical gauge coverage is inadequate?

- point-to-area
- coherent regions

Anomalies (%) of the EPI of Australia, smoothed with a 7-yr moving average filter. Recurrence intervals are 1 yr (with square markers), 5 yr (black), and 20 yr (gray). Fu et al. (2010) Fig. 6



#### 4. EXTREMES – Data sources

TMPA designed to give the “best” instantaneous estimate

- input data sources vary
- monthly TMPA SG
- 0.25°, 50°N-S, 3-hr→daily

1DD more approximate, relatively homogeneous

- match-up of single SSML, then SSMIS with geo-IR
- monthly GPCP SG
- 1°, 90°N-S, daily

## 4. EXTREMES – Climate-oriented indices

Acknowledge CCI/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) concept of “core indices”

Chose to compute

- **Ravg**            *Avg. daily precip*
- **Rfrac**            *Avg. fraction of days with precip ( $> 0.5$  mm/d)*
- **R95p**            *95th-percentile precip rate*
- **CWD**            *Avg. annual maximum length of wet spell ( $\geq 1$  mm/d)*
- **CDD**            *Avg. annual maximum length of dry spell ( $< 1$  mm/d)*

Introduce a dryness index:

- **f2mm**            *Avg. fraction of days with precip  $\leq 2$  mm/d*
- rough lower limit of agriculturally relevant event
- less sensitive to analysis artifacts than CDD

Record is too short to compute sophisticated metrics!

Note the paradox of “climate” variables depending on fine-scale estimates

- “extremes” easily contaminated by analysis artifacts
- R95p is computed because it is well-correlated to 99th percentile and maximum values, and is more stable

## 4. EXTREMES – CDD

Note: Color bar covers 12 months, versus 2 for CWD

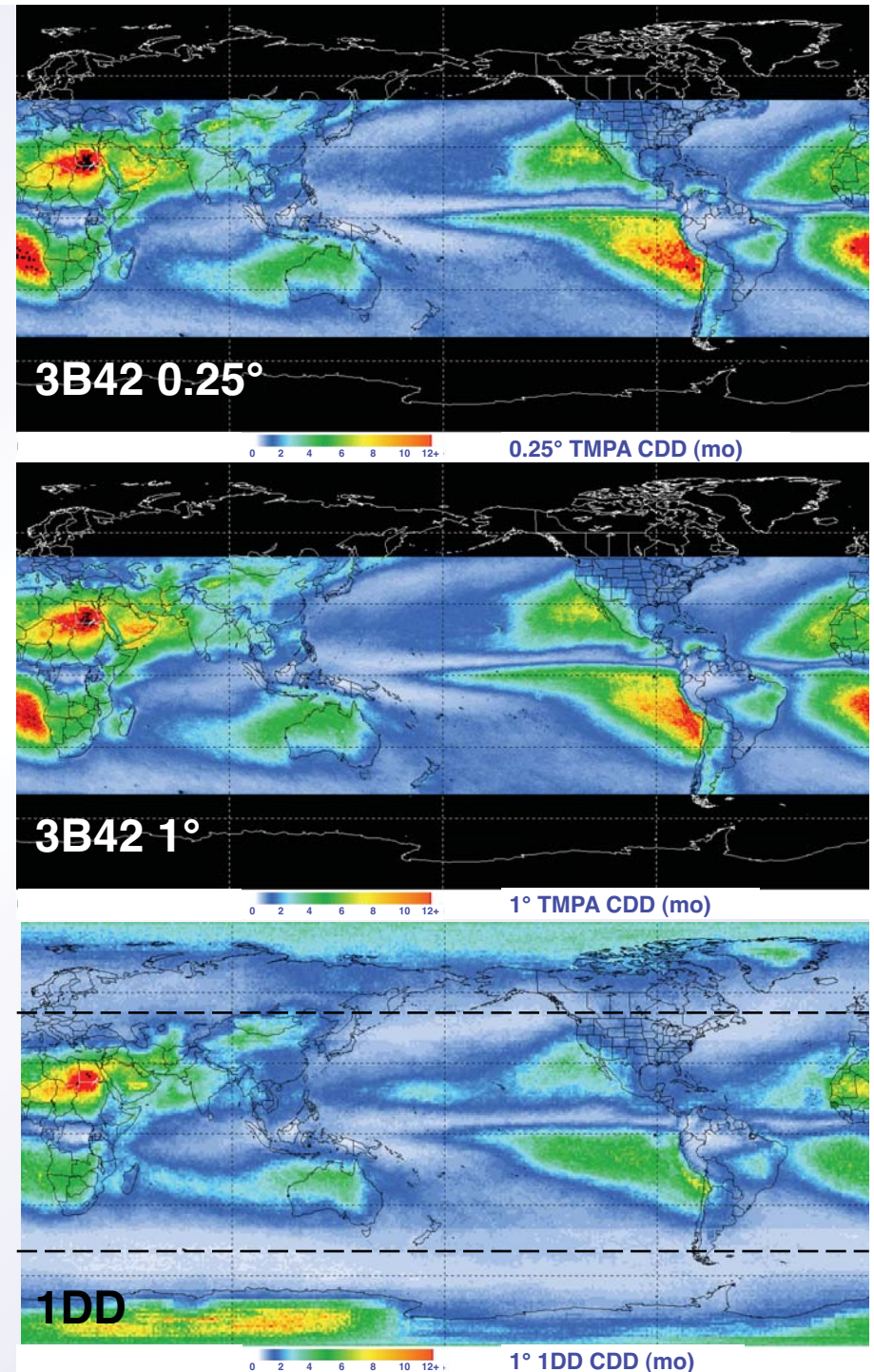
- rainy periods depend on individual storms

Spatial scale is not a major consideration (top, middle)

- dry spells tend to cover large areas

Different algorithms are systematically different (middle, bottom)

- 1DD generally lower, land and ocean
  - despite lower Rfrac around 20° N,S
- 1DD data boundary at 40° N,S not too important





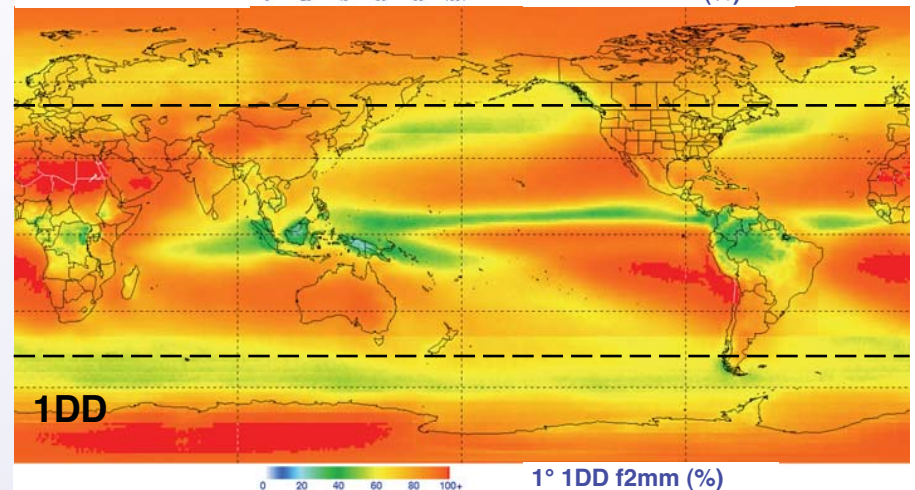
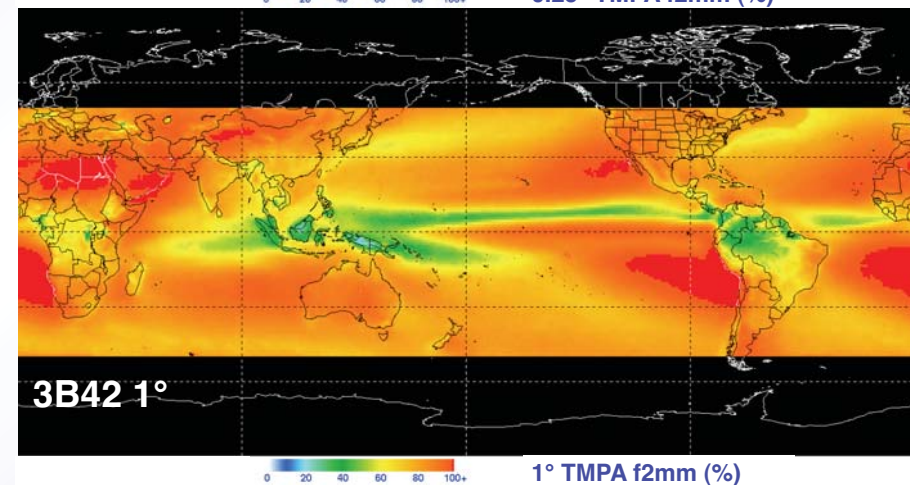
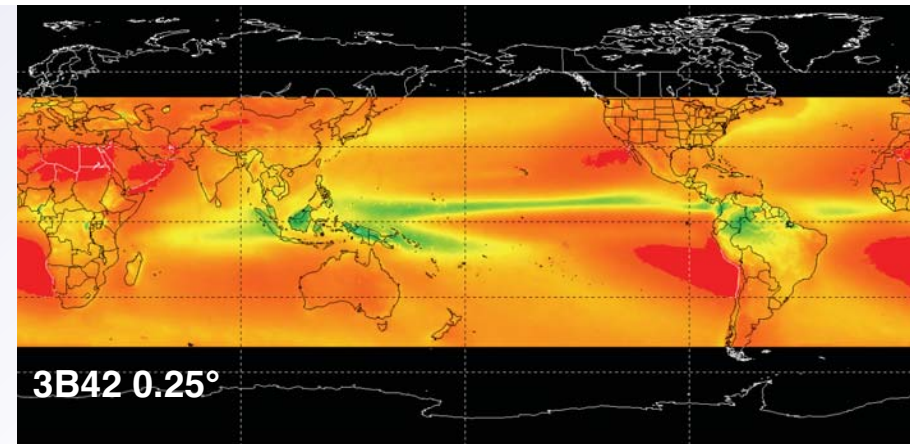
## 4. EXTREMES – f2mm

Spatial scale does matter (top, middle)

- heavy rain tends to be clumped together

Different algorithms are similar (middle, bottom)

- 1DD somewhat lower in central Africa
- 1DD somewhat lower in SPCZ, storm tracks
- (old) 1DD artificially lower in 40°-50° N and S latitude bands

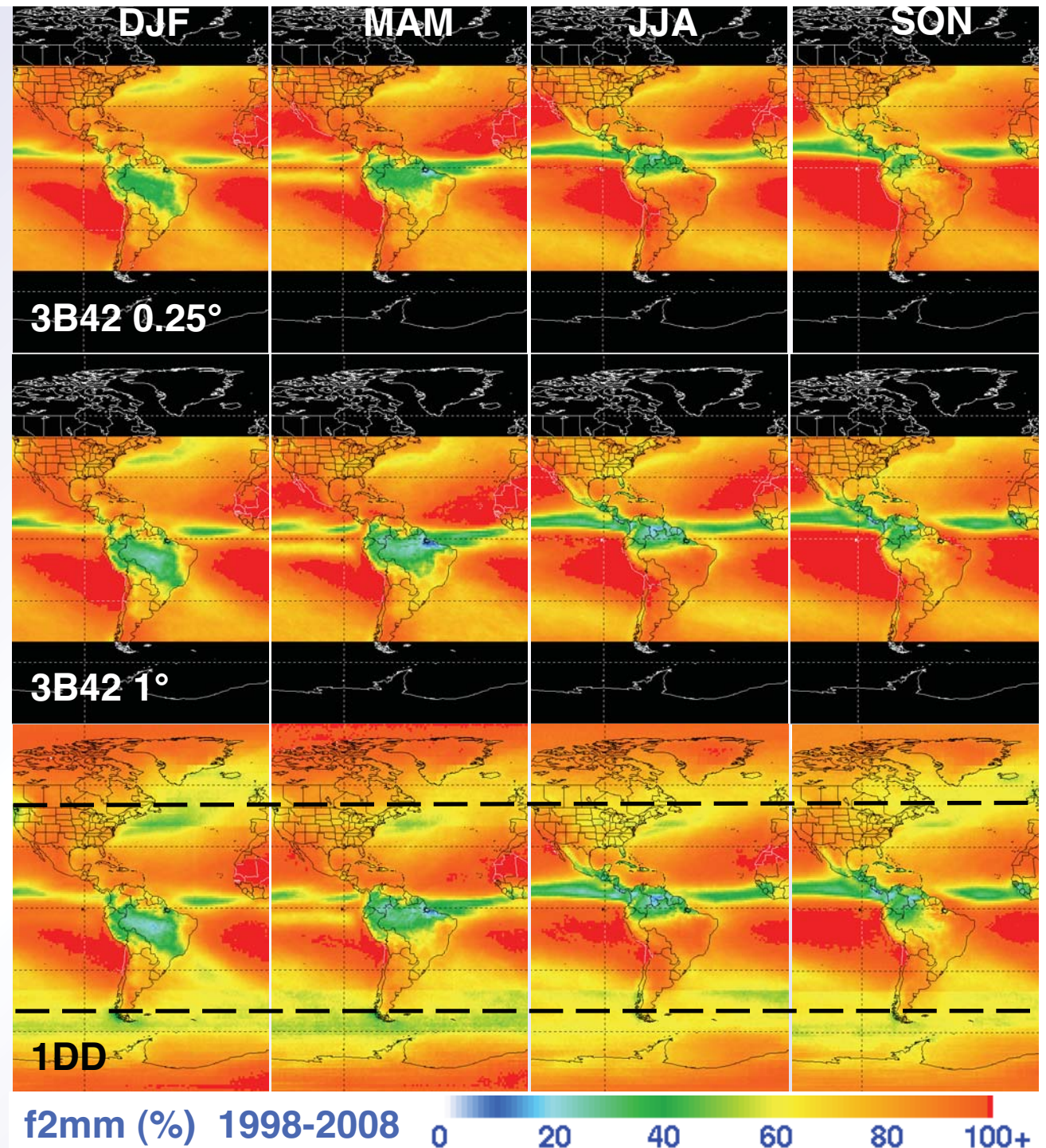




#### 4. RESULTS – f2mm seasonal climatology

Seasonal results mostly  
follow annual results

1DD slightly leads in  
Amazonia in transition  
seasons



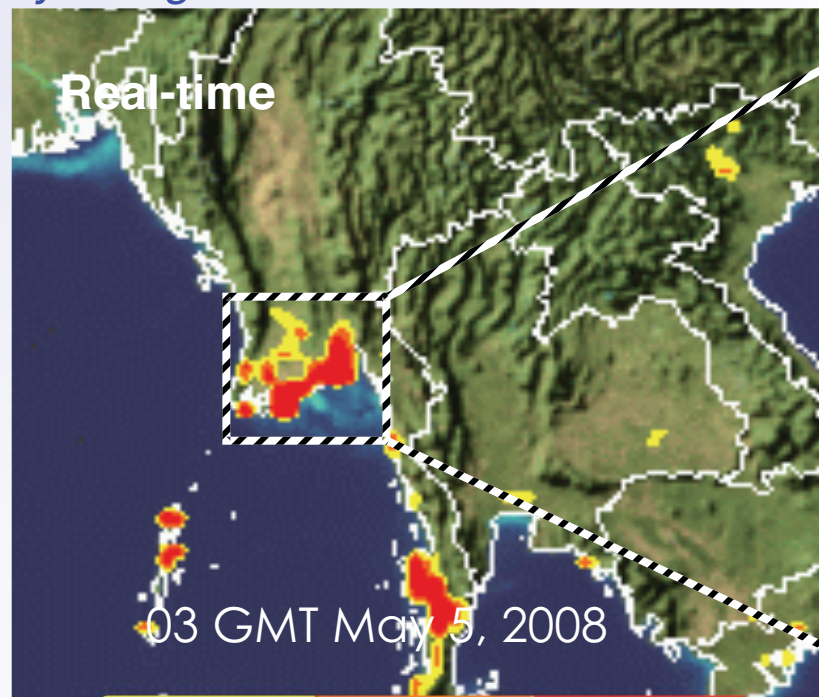


## 5. APPLICATIONS – Floods

Our precip group is also working on real-time flood and landslide alert systems

- in both cases, we use precip as the driver for simple models
- validation is a major problem, particularly for landslides
- MODIS inundation maps generally validate flood estimates from real-time hydrological estimations using satellite rainfall

*Real-time inundation estimate from hydrological model and satellite rainfall*

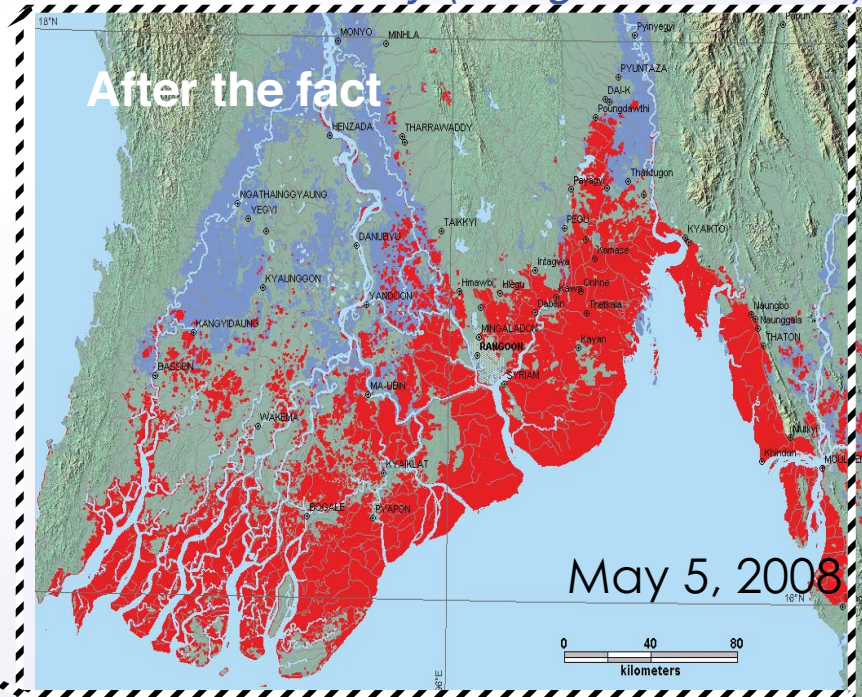


Flood Potential

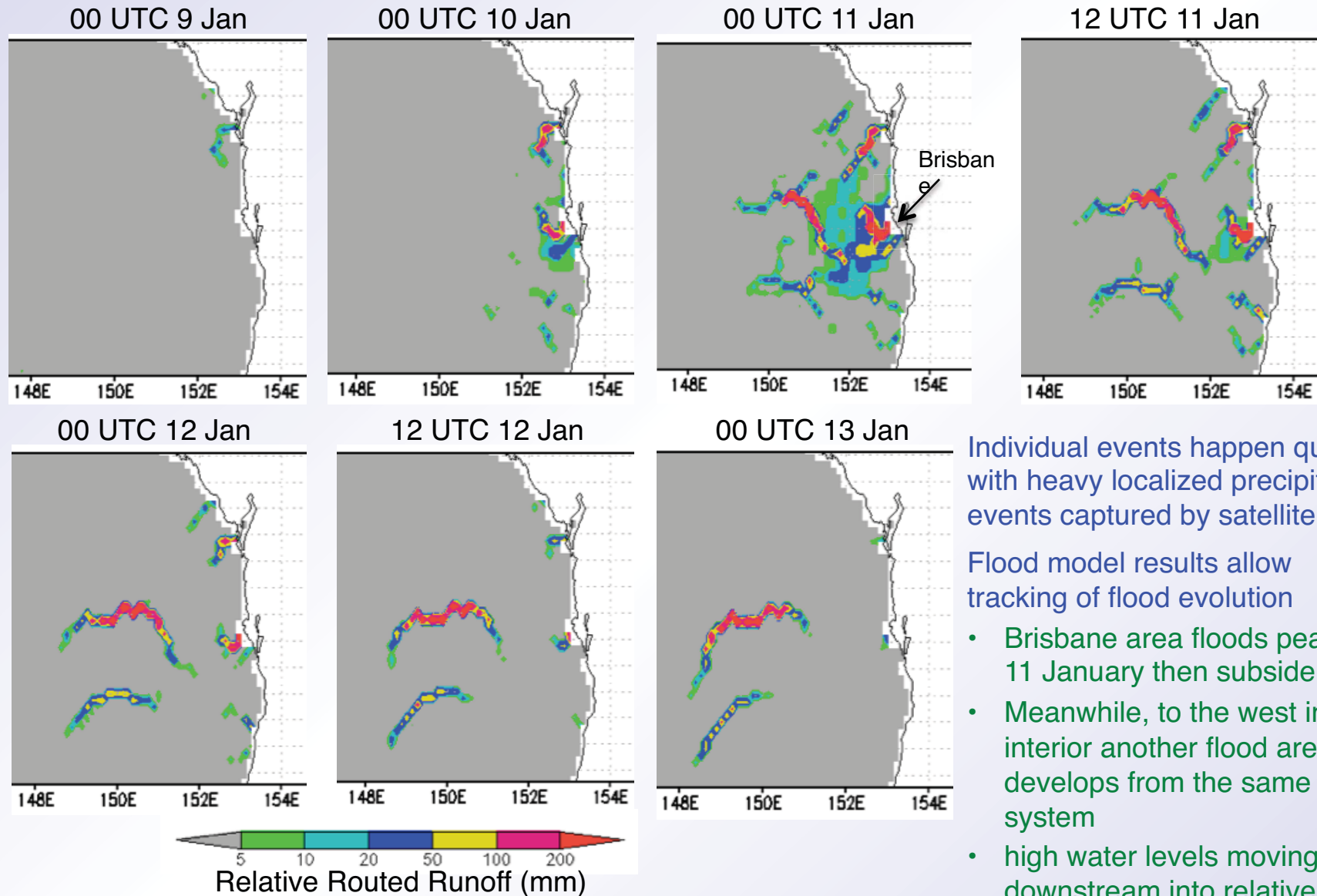
Flooding

Severe

*Post-event inundation map from Dartmouth Flood Observatory (using MODIS data)*



## 5. APPLICATION – Estimated flood evolution for 9-13 January 2011, Australia



Individual events happen quickly with heavy localized precipitation events captured by satellite data

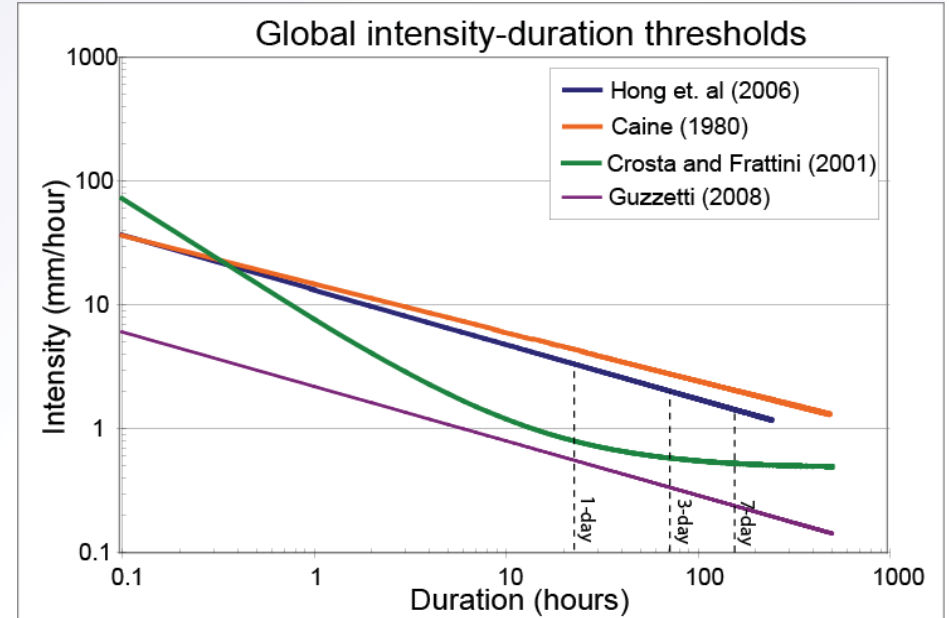
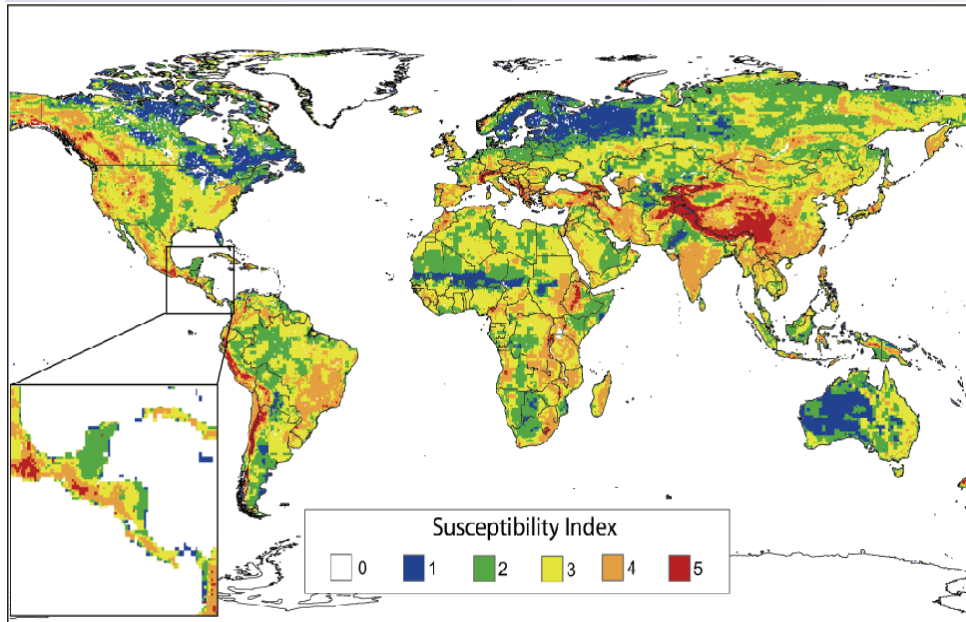
Flood model results allow tracking of flood evolution

- Brisbane area floods peak on 11 January then subside
- Meanwhile, to the west in the interior another flood area develops from the same rain system
- high water levels moving downstream into relatively unpopulated areas

*Adler (UMD), Wu (UMD), Tian (UMD), Policelli (GSFC), Hong (UOK), Pierce (SSAI)*

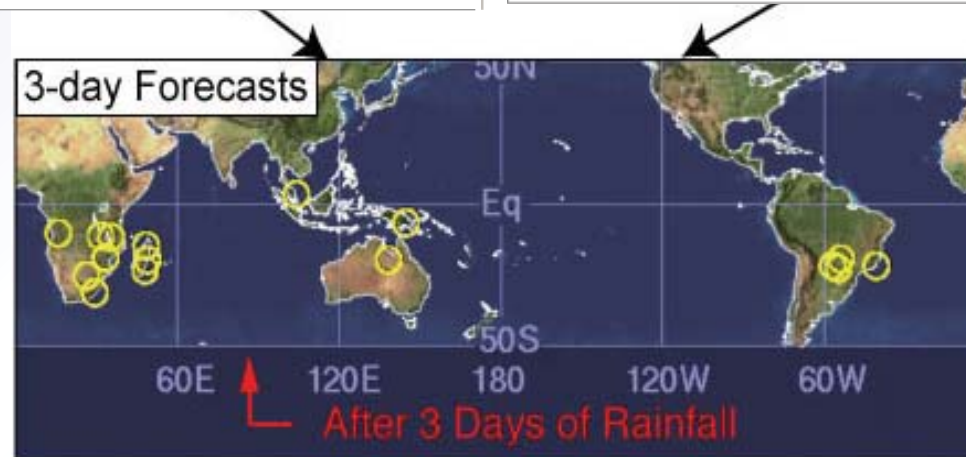


## 5. APPLICATION – Global Landslide Occurrence Algorithm



### Surface Data:

- topographic variables
- land cover
- soil type and texture
- drainage density



Circles enclose small areas of estimated landslide locations

### Rainfall Data:

- TMPA
- 0.25°, 3-hourly resolution

## 6. FUTURE – GPCP

V2.2 monthly SG, pentad, and daily are being re-worked in the NOAA CDR program

- Bob Adler, PI; Mat Sapiiano the main code jockey
- goal is to develop a renovated code set capable of running (semi-)automatically

V3 recently funded under MEaSUREs, for 5 years

- George Huffman, PI; Bob Adler, KuoLin Hsu, Mat Sapiiano, Pingping Xie, Co-I's
- shift to
  - new data streams
  - modern Level 2 algorithms
  - advanced merger techniques
  - finer time and space resolutions
- products are intended to cover the periods
  - 1979-present at the monthly and pentad time scales
  - 1982-present for daily
  - 1998-present for 3-hourly
- all products consistent (finer-scale approximately add up to coarser-scale)
- first beta products planned for Summer 2014

## 6. FUTURE – GPM combination (1/2)

The GPM Day-1 multi-satellite algorithm will be a unified U.S. algorithm

- Integrated Multi-satellitE Retrievals for GPM – IMERG
  - NASA TMPA: intersatellite calibration, gauge adjustment
  - NOAA CMORPH: Lagrangian time interpolation
  - U.C. Irvine PERSIANN: neural-net microwave calibrated IR
  - NASA PPS: input data assembly, processing environment
- 0.1°x0.1° half-hourly gridded data
- cover 50°N-S (later global) for the period 1998-present
- early samples expected Summer 2014
- at-launch runs will be computed with TRMM calibration
- TMPA, TMPA-RT will be computed until IMERG is approved in the GPM check-out

We will expand on the (near-)real-time and after-real-time production concept

- address different user needs in 3 “runs”
  - “early” (~4 hr after observation; flood, landslide)
  - “late” (~12 hr after observation; drought, crops)
  - “final” (with gauge, ~2 months after observation; research quality)
- episodic retrospective processing for all 3 runs

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- early samples expected
- at-launch runs will be
- TMPA, TMPA-RT will
- out

We will expand on the (r

- address different use
  - “early” (~4 hr after observation; Currently being used in CMORPH, GSMaP (Japan))
  - “late” (~12 hr after observation; drought, crops)
  - “final” (with gauge, ~2 months after observation; research quality)
- episodic retrospective processing for all 3 runs

Interpolate between PMW overpasses, following the cloud systems. The current state of the art is

- estimate cloud motion fields from geo-IR data
- move PMW swath data using these displacements
- apply Kalman smoothing to combine satellite data displaced from nearby times



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## 6. FUTURE – GPM combination (2/2)

We will continue seeking to employ all precip-relevant satellite data

- IR data from international geo-satellites (merged at NOAA)
- microwave data from “all” DoD, EUMETSAT, NASA, NOAA, other partner (Japan, France/India, ...) leo-satellites
- next-generation precip inputs from groups at NASA, NOAA; others in planning
- improved DWD precip gauge analyses

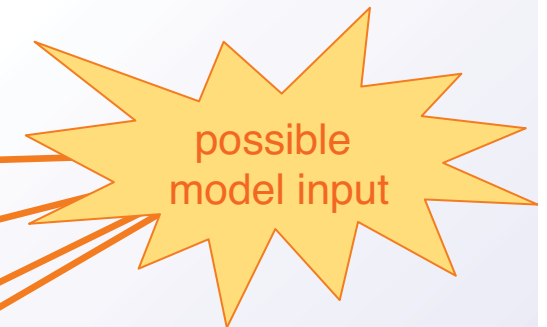
We expect to add a parallel model-observation product set

- model precip is better at high latitudes, satellite are better in the tropics
- IMERG framework is a natural for using both
- main issue is merging sometimes-very-different precip system depictions

## 7. CONCLUDING THOUGHTS – What Next?

The clear goal for Day-1 is operational code meeting GPM deadlines; after that ...

- implement a high-latitude scheme
  - develop high-latitude precip estimates science project
  - calibration schemes for high-latitude precip estimates
  - leo-IR-based displacement vectors
  - parallel observation-model combined product
- use sub-monthly (daily, pentad, or dekad) gauge analyses
- refined precipitation type estimates
- alternative scheme for computing displacement vectors science project
- address cloud growth science project
- convective/stratiform classification
- address orographic enhancement science project
- error estimates science project
  - bias and random
  - scale and weather regime dependence
- user-friendly formats and cutting-edge science
- intercalibrate across sensors with different capabilities science project
- revise precipitation gauge wind-loss corrections





## 7. CONCLUDING THOUGHTS – Other good things to know (1/2)

CMIP5 archive now contains observational data sets

- GPCP V2.2
- TMPA V7 3-hourly (3B42)
- TMPA V7 monthly (3B43)

The International Precipitation Working Group (IPWG) web site

- <http://www.isac.cnr.it/~ipwg/>
- a concerted effort in the next biennium to beef up user-oriented information
- there are already tables listing publicly available, long-term, quasi-global precipitation data sets
  - combinations with gauge data
  - satellite-only combinations
  - single-satellite
  - gauge analysis

The TOVAS web site

- <http://disc2.nascom.nasa.gov/tovas/>
- web-based interactive display and analysis for TMPA, TMPA-RT, GPCP, ...

## 7. CONCLUDING THOUGHTS – Other good things to know (2/2)

I'm pushing an "Area Average Special Interest Group" at GSFC

- get generic schemes up and running for computing averages
  - over arbitrary areas (shapefiles)
  - from gridded data
- from the start I've gotten requests for "the time series of rainfall over Uganda"
- historically this was only easy in proprietary GIS systems
- but recently
  - shapefile collections for countries, political subdivisions, river basins are on the web
  - computer power is increasing
- three GSFC groups are interested, more are welcome

Error estimation is a major issue

- errors are a weird amalgamation of errors from inputs, sampling, and combination
- user requirements are fuzzy at best
- monthly random error estimate is reasonable
- monthly bias has some draft concepts
- short-interval error is a work in progress

## 7. CONCLUDING THOUGHTS – Recap

Precipitation is a tough, important problem

- Driven by the microscale

Most users benefit by using combined datasets

- Intercalibration is important
- Precipitation gauge data usually important
- Combination schemes are under vigorous development
- There are two streams
  - CDR for climate (roughly)
  - HRPP for weather (roughly)

Error estimates remain as a key problem

- Bias and random error resist easy solution
- Mismatch with user expectations is a problem, particularly the random error for HRPP's

## 7. CONCLUDING THOUGHTS – References

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, **8**(1), 38-55.

Huffman, G.J., R.F. Adler, D.T. Bolvin, E.J. Nelkin, 2010: The TRMM Multi-satellite Precipitation Analysis (TMPA). Chapter 1 in *Satellite Applications for Surface Hydrology*, F. Hossain and M. Gebremichael, Eds. Springer Verlag, ISBN: 978-90-481-2914-0, 3-22.

Huffman, G.J., D.T. Bolvin, 2011: Real-Time TRMM Multi-Satellite Precipitation Analysis Data Set Documentation. [ftp://meso-a.gsfc.nasa.gov/pub/trmmdocs/rt/3B4XRT\\_doc.pdf](ftp://meso-a.gsfc.nasa.gov/pub/trmmdocs/rt/3B4XRT_doc.pdf), 45 pp.

Huffman, G.J., D.T. Bolvin, 2011: TRMM and Other Data Precipitation Data Set Documentation. [ftp://precip.gsfc.nasa.gov/pub/trmmdocs/3B42\\_3B43\\_doc.doc](ftp://precip.gsfc.nasa.gov/pub/trmmdocs/3B42_3B43_doc.doc), 29 pp.

**Precip Group Page:** <http://precip.gsfc.nasa.gov>

**Contact:** [george.j.huffman@nasa.gov](mailto:george.j.huffman@nasa.gov)



## 4. EXTREMES – Ravg

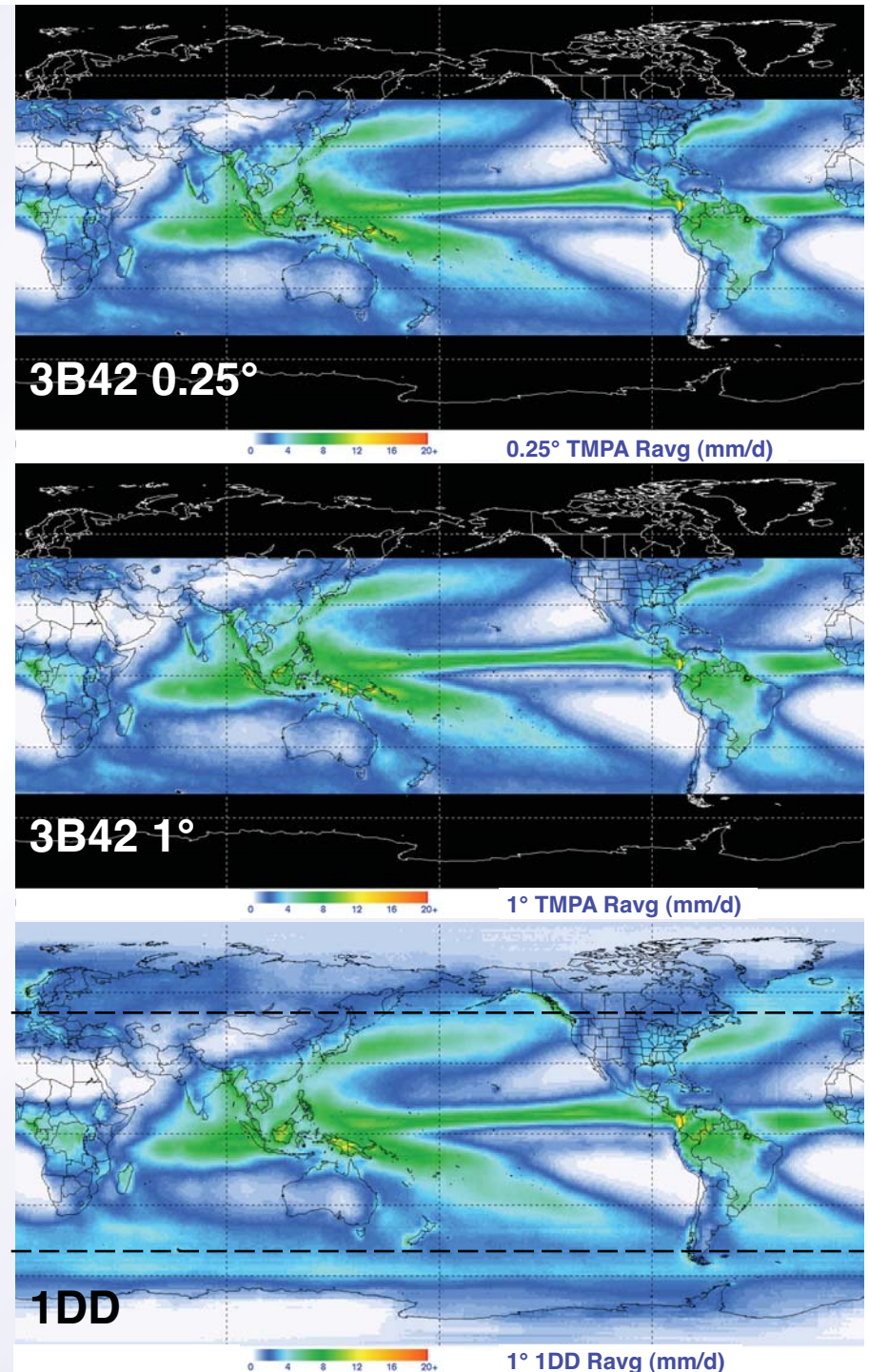
Important design goal for both data sets

- mostly reflects monthly SG
- land very similar due to similar (monthly) gauge analyses

Spatial scale not a major consideration (top, middle)

1DD wetter at higher latitudes due to construction of GPCP monthly SG

- likely GPROF artifact around Newfoundland



## 4. EXTREMES – Rfrac

An important design parameter, but not generally validated

Spatial scale is a major consideration (top, middle)

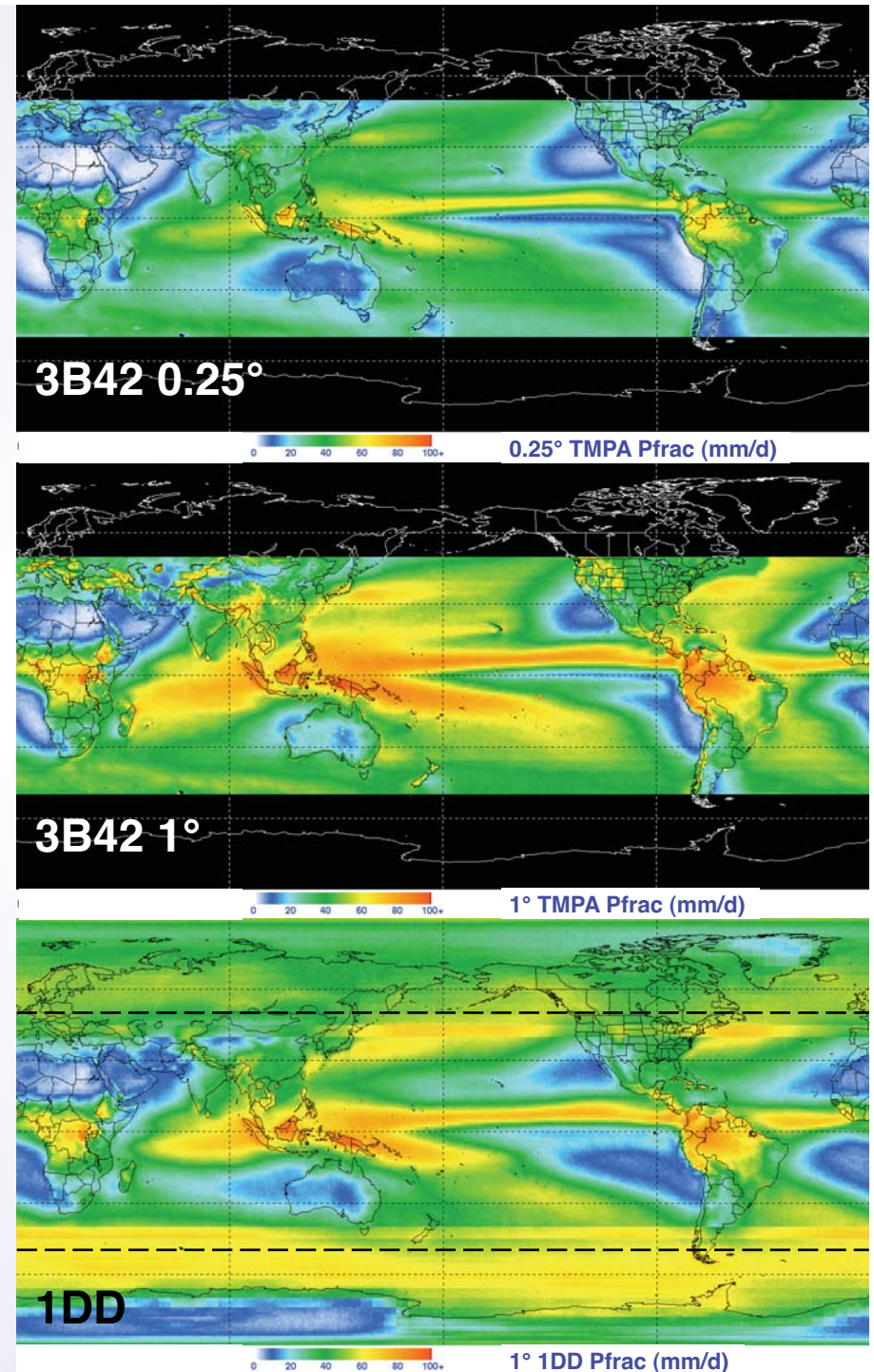
- any rainy 0.25° gridbox yields a rainy 1° gridbox

Different algorithms agree rather well (middle, bottom)

- driven by short-interval values, not monthly SG scaling

Differences:

- again, TMPA fades out at mid-latitudes
- TMPA low-precip artifact around Newfoundland is clear
- (old) 1DD's linear fade for latitude bands 40°-50° N,S artificially increases Rfrac
- TMPA much higher around 20° N,S, which needs more study





## 4. EXTREMES – R95p

Spatial scale is a major consideration (top, middle)

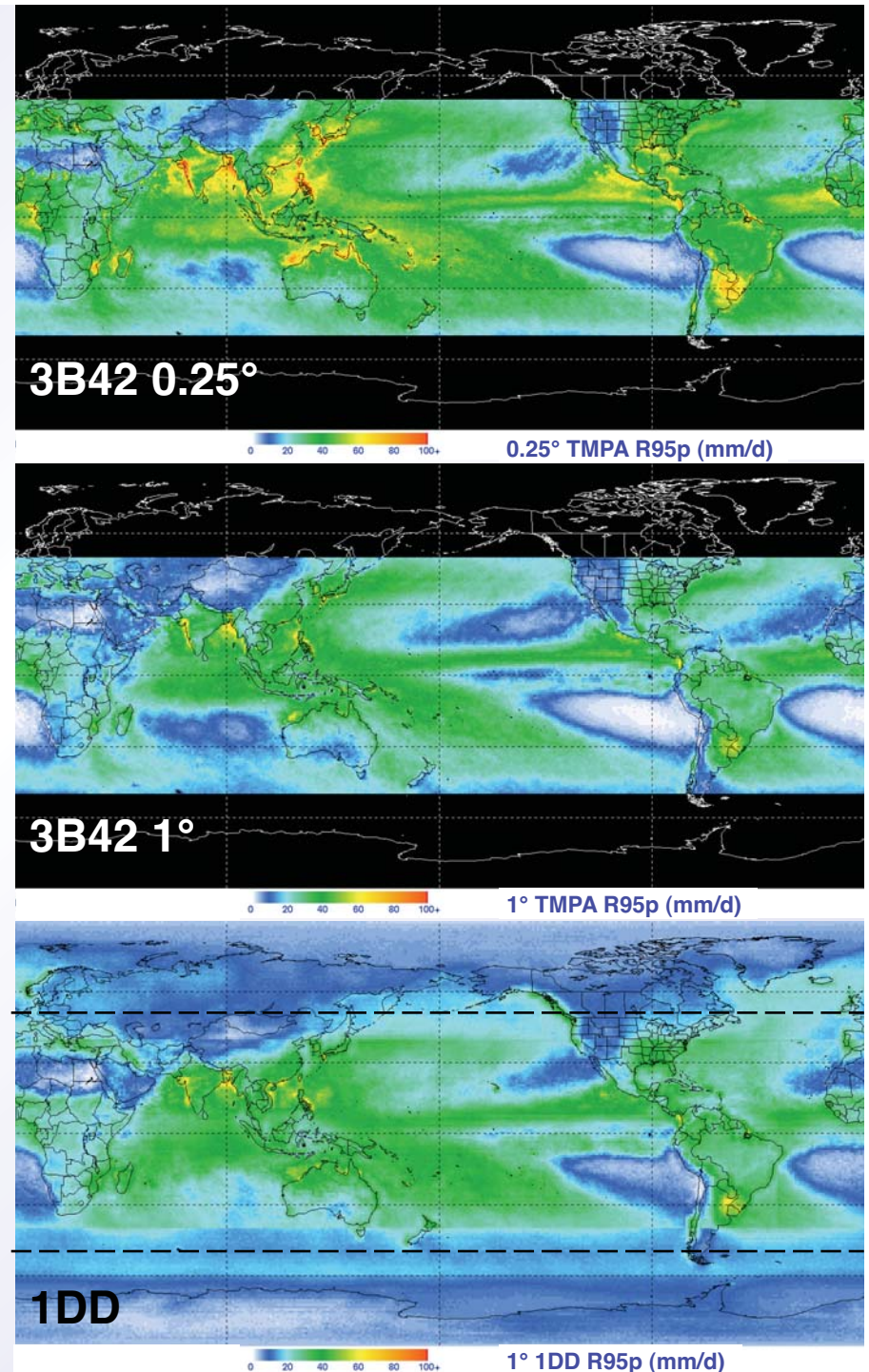
- high rain values tend to be small-scale, so averaging tends to reduce the highest values

Different algorithms agree rather well (middle, bottom), particularly for land

- structures around Newfoundland are similar

Differences:

- 1DD is higher around 20° N,S, opposite of Rfrac result
  - 1DD tail is fatter
  - perhaps TMPA's AMSU input depresses averages?
- 1DD lower outside 40°N-S - current TOVS/AIRS algorithm has low maxima



## 4. EXTREMES – CWD

Spatial scale is a major consideration (top, middle)

- as with Rfrac, averaging increases chance of picking up a rain event

Different algorithms agree rather well (middle, bottom), particularly for land

Differences:

- TMPA fades out at higher latitudes
- extra bump in (old) 1DD in the linear fade regions (40-50° N,S)

